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EXERTION AROUSAL, PERSONALITY
AND MENTAL PERFORMANCE

by

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ABSTRACT

The purpose of this study was to examine the effect of physical exertion on mental performance. It was hypothesized that physical exertion may be one of many factors that influence the level of arousal and hence affect mental performance.

Specifically 80 subjects were divided into four groups on the basis of their extreme scores on the Eysenck Personality Inventory which measures personality in terms of extraversion-introversion, and neuroticism-stability. Each student was then subjected to varying amounts of physical exertion, after which their mental performance was measured on the Wechsler digit recall short term memory test, and the Brown and Poulton test of attention.

A 2 x 2 x 6 (extraversion x neuroticism x exertion) analysis of variance with repeated measures on the last factor was calculated on both tests of mental performance. Some significant results were analysed by the Newman-Keuls procedure.

Short term memory scores were found to deteriorate significantly after 4 and 6 minutes exertion, but remained almost constant with exertion less than 4 minutes. However, performance on the Brown and Poulton test improved significantly after periods of 1/2, 2 and 4 minutes exertion, and thereafter performance began to deteriorate with increasing exertion. These results were consistent with Duffy's view that as arousal increases, performance improves to an optimal level, and thereafter, as arousal increases, performance begins to deteriorate.

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In support of the concept that physical exertion may produce arousal, some interaction effects between the personality variables were found to be significant. With the same amount of exertion introverts were found to deteriorate in performance before extraverts, thus lending support to Eysenck's theory that introverts are more highly aroused than extraverts in a resting state, and reach their optimal level earlier with increasing arousal.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

According to Birch and Veroff (1966), human behaviour may be analysed by means of the following dimensions: (i) direction, (ii) intensity and (iii) persistence. For many years previously Duffy (1934, 1962) had argued that variations in behaviour may be described as variations in direction or intensity of behaviour. Since an organism may approach or withdraw from a stimulus, and this approach or withdrawal may take place with varying degrees of intensity, and for varying periods of time, Duffy argued that there are many situations from which a person may approach or withdraw, and this characteristic may be designated as the direction of behaviour. Similarly, since there are varying degrees of approach or withdrawal occurring over different periods of time, these aspects may be called intensity and persistence of behaviour. For example, approach or withdrawal may occur at a low degree of intensity or a high degree of intensity or at an intermediate degree of intensity. According to Duffy the intensity of response is measurable in terms of the force of overt action or in changes in the internal processes associated with the release of energy. Duffy contends that a concept of intensity based upon the measurement of internal processes is a much more useful construct than one based on the force of overt response. Such a concept is called the level of arousal although over the years it has variously been referred to as degree of excitation, energy mobilization, drive, emotion or level of activation.

This study is concerned with the concept of arousal and the influence it may have on one particular facet of behaviour, namely mental performance. Arousal, as defined at this point, is considered to be a neuropsychological concept, referring on the neural side to the state of excitation of the reticular formation of the brain stem, and on the psychological side to the common core in such terms as awakeness, alertness, attention, tension and subjective excitement (Fiske and Maddi, 1960, p. 135). In defining arousal Hebb (1966) includes vigilance to the above terms.

Although not in complete agreement with each other, many workers (Lindsley 1951; Hebb 1955; Malmo 1959; Berlyne 1960; Duffy 1962, 1968) appear to have summarized the concept of arousal and its influence upon behaviour. In general there is agreement that arousal is a continuum ranging from low to high, with the optimum degree of arousal for a particular type of behaviour being of moderate intensity. That is, the curve which expresses the relationship between the quality of behaviour and arousal is in the form of an inverted U, i.e. performance improves with increased arousal but deteriorates with further increase beyond the optimal level. As Lindsley (1951) states, from low arousal up to a point that is optimal for a given function, level of performance rises monotonically with increasing arousal level, but beyond this point produces a fall in performance level, this fall being directly related to the amount of increase in level of arousal. (The above statements are purely a restatement of part of the original Yerkes-Dodson (1908) principle which suggested a curvilinear relationship between motivation and performance.)

However, there is less agreement amongst the writers mentioned as to the stimulus conditions that produce arousal and their influence upon specific aspects of behaviour. Various authors attempt to distinguish between the stimulus conditions by using terms such as, "Fear Arousal" (Janis, 1967), "Anxiety Arousal" (Janis and Feshback, 1954), "Emotional Arousal" (Oxendine, 1970), "Shock Arousal" (Marteniuk, 1969), "Noise Arousal" (McBain, 1961) and "Heat Arousal" (Provins, 1972). Some writers, (Lindsley 1951; Duffy 1962; Gutin 1970; Stockfelt 1968) have suggested that one such stimulus condition that produces arousal is physical exertion. This research is to be concerned with, "exertion arousal", and its influence upon one form of behaviour, i.e. the influence of physical exertion upon mental performance.

Physical education, by its very nature is concerned with physical exertion, so that if the stimulus of physical exertion may be shown to alter the level of arousal which may influence mental performance, then physical educators should be cognizant of this relationship. Many writers, (Fitts 1961; Bruner 1961; Crossman 1964; Welford 1968) have emphasized the cognitive and perceptual aspects of skill learning and performance; for example, Fitts states that skills need to be intellectualized or conceptualized, and that at advanced levels cognitive aspects involve strategy, judgement, decision making and planning. Also he suggests that the perceptual aspects of skill learning include learning what to look for, how to identify important cues, and how to make critical discriminations. If physical exertion may be shown to influence the level of arousal, then this study may contribute to improved human performance by improving the cognitive and perceptual aspects which

accompany movement.

The Problem

The present problem arose from the persistent observation that many athletes (middle and long distance runners, footballers, bike-riders) appeared to make wrong decisions at a crucial stage in their performance, which eventually lowered the standard of their performance. After the event the athlete was aware of his wrong decision, but apparently felt powerless at the time to make the correct decision. It was thought that perhaps the athlete in a state of oxygen debt may have a condition of cerebral hypoxia, which could interfere with the decision making mechanism. A thorough search of the literature failed to find evidence to substantiate this possibility. Hence a series of pilot studies were begun in order to investigate this problem.

These pilot studies attempted to simulate the conditions of the athlete in the laboratory by giving various subjects a controlled amount of physical exertion, and by measuring their performance on a mental task before and after exertion. The results of these preliminary studies (Davey 1968, 1972a, 1972b) indicated that physical exertion may influence the level of arousal and the present study was initiated in order to investigate the problem further.

The purposes of the study are:

(a) To investigate the concept of arousal as it relates to and is produced by physical exertion.

(b) To discover the influence of arousal (produced by physical exertion)

upon mental performance.

(c) To determine whether the psychological traits of extraversion-introversion, neuroticism-stability affect the optimal level of arousal produced by physical exertion.

(d) To test the following hypotheses:

  (i) that physical exertion influences mental performance,

  (ii) that varying amounts of physical exertion differentially influences mental performance, and

  (iii) that the psychological traits of extraversion-introversion and/or neuroticism-stability influence the level of arousal produced by physical exertion.

Importance of the Study

Although many studies have been conducted to examine the effect of physical exertion upon mental performance, conflicting research has been published and some clarification is needed. For example, Freeman (1933) after surveying the literature to date, stated that, "muscular exertion may,

  (i) increase mental performance

  (ii) have no effect upon it, or

  (iii) be actually inhibitary."

A number of factors appear to contribute to the many discrepancies that have arisen. Firstly the problem has been attacked from two different directions. Whereas the early workers (Loeb 1888; Lehmann 1900) were concerned with observing the influence of mental performance upon

muscular tension (later to be called arousal), later workers (Bills 1927; Courts 1939) were concerned with increasing muscular exertion and observing its effect upon mental performance.

A second explanation for the variation between the findings may be the various methods that have been used to measure muscular exertion. Most of the early researchers used crude but rather elaborate mechanical systems of measurement, whereas later workers were able to use electrical systems which were far more sensitive.

A further complication has arisen in the measurement of what has been termed mental performance. The most common form of mental performance used has been serial rote learning tasks involving nonsense syllables, paired associates, etc., as well as many non-verbal tasks including multiplication or addition of digits. Verbal reasoning, syllogistic reasoning, detectograms and the solving of arithmetical problems have also been used. To add to the confusion, there has also been controversy as to whether mental performance was better measured by the quality or the quantity of the work done.

Hence, in examining the various methods used up until the middle sixties, the studies which dealt with the relationship between muscular exertion and mental performance have been found to be correlated positively, negatively or not at all with each other.

However, two researchers in physical education have renewed earlier efforts in an attempt to understand this important relationship. Gutin (1966, 1968a, 1968b, 1970) with some encouraging results expressed the opinion that the effect of physical exertion on learning skilled tasks required further investigation. Stockfelt (1968) was optimistic of his

findings on research with exertion, arousal and performance, but emphasized that it was only, "a beginning of the beginning, but results so far should encourage us to continue".

Welford (1965) suggested that, "as the concept of arousal has such widespread implications and research has reached the stage where practical applications are beginning, it is clear that it is worthwhile to try to find out more".

Also, Oxendine (1970) has stated that, "understanding the optimal level of arousal for each activity is only part of the information needed to make effective its use in motor skills. Also needed is the ability to alter the level of arousal of a particular individual at a particular time. Such a topic is appropriate for a major investigation".

There has recently been a number of writers who have suggested that individuals differ characteristically both in their resting level of arousal and in the change in arousal produced by stress, and that these parameters are related to the personality traits of extraversion-introversion and neuroticism-stability. (Welford 1965; Eysenck 1967; Kane 1972). Therefore, this study will attempt to discover whether such personality traits can be related to arousal produced by physical exertion.

Finally it is hoped that this research may in part answer some of the queries raised by Walters (1966) in a symposium on motor learning when he stated that, "it would appear that the wise teacher or coach should be aware of the part arousal plays in optimal performance."

Delimitations

(a) The sampling of subjects will be limited to male and female students in the 19-21 age range in the physical education course at the University of Melbourne.

(b) Also the study is limited by the adequacy of the various tests to measure the required criterion.

Definition of Terms

For the purpose of this investigation the following operational definitions will be used:

(a) Physical exertion is the amount of work done by the act of pedalling a constant torque bicycle ergometer at a uniform rate. Work done is measured in foot pounds.

(b) Mental performance is an individual's total score on the Brown and Poulton (1961) test. This test measures the ability to identify a given series of numbers from a continuing series and relies heavily on the short term memory.

(c) Extraverts are those subjects scoring on the most extreme end of the extravert dimension on the Eysenck Personality Inventory (E.P.I.).

(d) Introverts are those subjects scoring on the most extreme end of the introvert dimension of the E.P.I.

(e) Neurotic subjects are those who score most highly on the neuroticism dimension of the E.P.I.

(f) Stable subjects are those who score the least on the neuroticism dimension of the E.P.I.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter will first discuss the various theories of arousal and will be followed by an analysis of the findings of research on arousal and performance. The literature pertaining to the influence of personality on arousal, and hence performance will also be examined and a summary will be given after each section.

For the sake of consistency, the term arousal will be used throughout although some authors prefer the term activation. However many writers (Welford, 1968, Hebb, 1955) feel the terms are interchangeable.

I. Theories Concerning Arousal and Performance

Behavioural Approach

As stated previously, Duffy (1932, 1941, 1957, 1962) has developed the concept of arousal over many years, although she admits that the historical roots of the concept came from Cannon's (1929) idea of energy mobilization during emotion. However unlike Cannon, she restricted the use of the term to describe the intensity aspect of behaviour.

Duffy (1957) felt the need for this concept because of the fact that an individual - the organism as a whole - is sometimes excited, sometimes relaxed, and sometimes in a variety of intermediate conditions. Also she acknowledged that the various systems of the organism are not equally activated at a given moment, but that the organism, as a whole, shows higher or lower degrees of excitation, and not just a particular system within the organism e.g. the skeletal muscles.

Objections raised to her concept of general arousal are answered as follows:

(a) the first objection was that the concept of general arousal referred to something non-physiological over and above the totality of the activation of various parts of the organism. She replied to this criticism by saying that the term did not refer to psychic energy or any mysterious excitation of the tissues, but that arousal may be defined in terms of such excitation as measured by the various indices, such as heart rate, skin resistance, muscular tension etc. (In later writings Duffy (1962) adds to this list the measurement of the electroencephalograph, E.E.G.)

(b) a second objection correctly stated that it was not clear how this general arousal should be measured and Duffy agreed with this. But, she stated that although we have yet to discover the best technique for measuring arousal, nevertheless, many researchers had found, "a general response pattern" consisting of increased muscular tension, increased sweat gland activity, increased heart rate and increased respiration rate and amplitude. These responses she claimed, were said to behave with reasonable consistency from subject to subject under experimental conditions.

(c) a third objection was raised that because of the low intercorrelations of physiological measures, this suggested a less integrated functioning of the organism than the data of either physiology or everyday observation would make plausible. However, Duffy insisted

that the low correlations still existed and accounted for them as follows:

(i) Various physiological functions may reach a peak whilst another is just beginning to be activated.

(ii) Duffy (1962) quoted Lacey (1956) who stated that in nearly half the population at least, excitation may, in constant fashion, be shown most markedly in one system by one individual, and in another system by another individual. Although this made the measurement of arousal more difficult, it did not negate the conception of an aroused individual, rather than merely an activated system within the individual.

(iii) Whilst intercorrelations of physiological measures were generally low, intracorrelations of measures within the same individual were considerably higher. This, she stated, was what a concept of general arousal required.

The chief point which Duffy (1962) made with regard to arousal was that it occurs on a continuum from a low point during sleep, to a high point during extreme effort as excitement with no visible distinguishing breaks. The stimuli which she stated produce variations in the degree of arousal ranged from emotion, hormones, drugs, physical exertion to the degree of motivation.

In general, Duffy stated that the optimal degree of arousal appeared to be a moderate one, with the curve which expressed the relationship between arousal and performance having the form of an inverted U. However she felt that the effect of any given degree of arousal upon performance

appeared to vary with a number of factors including the nature of the task to be performed and certain characteristics of the individual (e.g. the ability to inhibit and co-ordinate responses). She also hypothesised that differences in the degree of arousal (some people were more responsive to arousal than others) in different individuals may have a genetic or an environmental basis or both.

Although Duffy suggested the possibility of a relationship between personality variables and arousal, she looked to others to further investigate the problem. Not at any stage did she offer an explanation of the causal relationship between arousal and performance.

Neurophysiological Approach

On the basis of many new developments in neurophysiology (e.g. Jasper 1941, Moruzzi and Magoun 1949) Lindsley (1951) adopted a neurophysiological approach to arousal theory.

Jasper (1941) discovered distinctive E.E.G. wave patterns characterizing the main levels of behaviour from deep sleep to highly alerted states of activity; e.g. in deep sleep large low frequency waves predominate, whereas in relaxed wakefulness the frequencies are not as low as in deep sleep, but there are more low frequency waves than in the wakeful states. In relaxed wakefulness there is a predominance of waves in the alpha (8-12 c.p.s.) range that gives way to beta frequencies (18-30 c.p.s.) when the person is moderately alert. Under conditions of heightened alertness there is a change from a regular synchronized appearance of the tracing to an irregular desynchronized tracing of reduced amplitude. For Lindsley the appearance of desynchronization

on the E.E.G. tracing was what he called the "arousal pattern" although he could offer no explanation as to the neural mechanisms involved.

With the discovery of the ascending reticular activating system (A.R.A.S.) by Moruzzi and Magoun (1949) there was a rapid and very significant advance in theory and experimentation. For example, Lindsley (1957) felt the two most important findings were:

(a) lesions in the A.R.A.S. abolished arousal of the E.E.G. and produced a behavioural picture of lethargy and somnolence, and,

(b) the arousal pattern in the E.E.G. was reproduced by electrical stimulation of the A.R.A.S.

In his earlier work, Lindsley (1951) appeared to limit his concept of arousal to emotional arousal and showed the effect on the E.E.G. pattern of unexpected sensory stimulation in apprehension and anxiety. However, although he did not refer to the inverted U theory with regard to performance and arousal level, he realized that under mild emotion - the so called pleasant and relaxed states - the E.E.G. pattern, and hence arousal level, was less disrupted. He felt that arousal theory could only account for the extreme states of emotional response (e.g. maximum excitement, relaxation and sleep), but it left the intermediate and mixed states relatively unexplained.

<u>Drive Approach</u>

A third approach to arousal theory has been made by the learning theorists, especially those of the Hull school, e.g. Hebb (1955). Before considering Hebb's theory it is necessary to make clear his meaning of the words, "motivation" and "drive". He suggested that

motivation referred in a general sense to the energizing of behaviour, and especially to the sources of energy in a particular set of responses that keep them temporarily dominant over others that account for continuity and direction of behaviour. Drive, he regarded as a more specific conception about the way in which this occurred; a hypothesis of motivation, which makes the energy a function of a special process distinct from those S-R or cognitive functions that are energized. In some contexts however, Hebb maintained that motivation and drive are interchangeable.

Hebb stated that the arousal system can be thought of as representing a second major pathway by which all sensory excitation reached the cortex, but there was also feedback from the cortex. He felt that in general terms it was possible to distinguish two quite different effects of a sensory event. One was the cue function, guiding behaviour; the other less obvious but no less important was the arousal or vigilance function. Without a foundation of arousal he stated that the cue function could not exist.

Hebb proposed that in this sense arousal was synonymous with a general drive state, and his conception of drive therefore assumed anatomical and physiological identity. He saw drive as an energizer, not a guide. Also he stated that since learning was dependent upon drive, then, in general terms, if there were no arousal there would be no learning. He continued by saying that efficient learning was only possible in the waking, alert, responsive person in which the level of arousal was high.

Physiologically he assumed that cortical synaptic function was

facilitated by diffuse bombardment of the arousal system. When this bombardment was at a low level, an increase tended to strengthen or maintain the current cortical activity; however, when this bombardment was at a high level, an increase tended to lower the current cortical activity. For example, as the level of arousal increased so the level of cortical activity increased also; however, when arousal was at a high level the greater bombardment interfered with the delicate adjustments involved in cue function, perhaps by facilitating irrelevant responses. In Hebb's own words, "a high D (drive) arouses conflicting $S^{H}R$'s.

Consistent with the inverted U proposal he agreed that there would be an optimal level of arousal for effective behaviour. Nevertheless he postulated that the same stimulation in a mild degree may attract, (by prolonging the pattern of response that led to the stimulation) and in a strong degree may repel, (by disrupting the pattern and facilitating conflicting or alternative responses).

An important point that Hebb makes in conclusion was that emotion was not synonymous with arousal, but that emotion did affect the level of arousal, particularly at the higher levels. In later writings Hebb (1966) appears to suggest that arousal is synonymous with his previously held ideas of a general drive state, and reserves the term drive for a specific need that is lacking, e.g. hunger, thirst, etc.

Neuropsychological Approach

In combining the previous three theories into one single dimension called the neuropsychological approach, Malmo (1959) suggested that they appear to lead to the same fundamental concept of arousal. He could not

offer a definition acceptable to each theorist, but contended that despite minor differences there was a large measure of agreement on the major characteristics of arousal. For example, all agreed with the following paradigm.

Arousal level:	Low	Moderate	High
Expected performance level:	Low	Optimal	Low

Malmo stressed that the measure denoted by "moderate arousal level", has a meaning only in relative, not absolute terms. That is the level is moderate only because it is higher than that of the low arousal condition, and lower than the level of the high arousal condition.

Summarizing the position he stated that, "the neuropsychological dimension of arousal may be described by the continuum extending from deep sleep at the low arousal end, to "excited" states at the high arousal end, and that this is a function of cortical bombardment by the A.R.A.S., such that the greater the bombardment the higher the arousal. The shape of the curve relating level of performance to level of arousal was that of an inverted U; from low arousal up to a point that is optimal for a given performance or function, level of performance rises monotonically with increasing arousal level; but past this optimal point the relation becomes non-monotonic; further increase in arousal beyond this point produced a fall in performance level, this fall being directly related to the amount of increase in the level of arousal."

Furthermore he listed the following characteristics of arousal:

(a) it has no steering function in behaviour;

(b) it is considerably broader than emotion;

(c) it is not a state that can be inferred from a knowledge of

antecedent conditions alone, because it is the product of an interaction between internal conditions and external cues;

(d) it does not fit very well into the S-R formula as it is a phenomenon of slow changes of drifts in level with a time order of minutes or even hours;

(e) it is a quantifiable dimension with the evidence indicating that physiological measures show a sufficiently high intra-individual concordance for quantifying this dimension.

Malmo's final suggestion was that arousal was mediated chiefly through A.R.A.S. which seemed to be responsible for the intensity system. He hoped that eventually neurophysiological research could achieve a more precise measurement of arousal as the concept has such important implications for behavioural scientists.

Reticular Formation

Most recent writers on the topic of behavioural arousal acknowledge its connection with the brain stem reticular formation. For example, Welford (1968) stated, 'the reticular formation is intimately concerned with arousal', whilst Cofer and Appley (1964) attributed the appeal of arousal theory to recent physiological discoveries with the reticular activating system.

In view of this relationship it is necessary to discuss briefly the reticular formation and its influence on behaviour. The reticular formation or reticular activating system are those areas at the base of the brain stem which are made up of a diffuse aggregation of cells of different types and sizes. It is believed to be essential for

cortical activities such as initiating and maintaining wakefulness - hence it is called the activating system. (Ruch and Paton 1965).

French (1957) stated that the reticular formation underlies our awareness of the world and our ability to think, to learn and to act. The actual seat of the power to think, to perceive, and to respond to any stimulus with anything more than a reflex action lies in the cortex of the brain, but according to French, stimulation of the cortex alone is not sufficient to awaken the brain. This,he stated,can only be done by the reticular formation, and he quoted Moruzzi and Magoun's (1949) experiments as evidence.

French explained that sensory signals from all parts of the body go to the cortex by direct pathways, but on the way to the brain stem they also feed into the reticular formation. When the reticular formation is so stimulated it sends arousing signals to the cortex which can then interpret the signals it is receiving directly.

Samuels (1959) showed that the reticular formation may be divided into two functional systems - the brain stem reticular formation and the diffusely projecting thalamic nuclei. Both these systems when activated induce a desynchronization of resting alpha rhythms throughout the cortex and this arousal response is generally correlated with a behavioural alertness of the organism. (Jasper 1949, Magoun 1954)

Samuels quoted many sources (e.g. Arduini and Moruzzi 1953; Bremer 1954; French et. al. 1952, 1953) which had established that all sensory modalities, both interoceptive and exteroceptive give off collaterals to both the brain stem and thalamic reticular systems. Hence visual, audiotry, olefactory, tactile, pain, proprioceptive and visceral stimuli

are all capable of activating both components of the reticular formation.

Samuels warned that although there were similarities between both reticular systems this should not obscure the differentiations which also existed. For example, he stated that one of the most striking differences concerned the arousal response itself, and quoted how Sharples and Jasper (1955) had distinguished between the two types of activation patterns. The first of these, sometimes called a 'tonic' reaction, referred to the brain stem reticular system, whereas the second, called a 'phasic' pattern, was a function of the thalamic system.

Eysenck (1967) drew attention to two most important connections within the brain, the first, the cortico-reticular loop and the second, the visceral brain and the reticular formation. Impulses which pass through the reticular formation send arousal messages to the cortex, which in turn instructs the reticular formation to continue sending arousal messages or switch to inhibition. This loop which is concerned with information processing, with cortical arousal and inhibition, is what Eysenck suggests as being responsible for the personality differences of extraversion-introversion. (These are discussed more fully in a later section).

The second loop concerning the visceral brain (hypothalamus, hippocampus etc. MacLean, 1958, 1960) and reticular formation has arousing effects on the cortex also, but this is produced by emotion. This loop concerned with emotion is what Eysenck feels is responsible for the personality differences of neuroticism-stability (also discussed later).

Hence Eysenck maintains that cortical arousal can be produced by two distinct and separate pathways, one direct from the reticular

formation without involving the visceral brain, the second involving the visceral brain, particularly the hypothalamus which Morgan (1965) stated was, 'the seat of the emotions'. Cortical arousal produced by emotions and subsequent activity in the visceral brain and reticular formation, is referred to by Eysenck as autonomic activation, and he reserves the term arousal to that produced by the reticular formation alone.

One further point of importance in view of the present study, is the fact that the secretion and circulation of the hormone epinephrine has been shown to have an effect upon the reticular formation.

Bonvallet et. al. (1954), Rothballer (1956), have said that the reticular formation is epinephrine-sensitive, whilst Jasper (1958) and Dell (1957) have both demonstrated that the cells in the reticular formation are sensitive to epinephrine and therefore this hormone may, in part, account for an arousing influence on the cortex (Jasper 1960).

Summary

Whilst Duffy may be credited with the development of the concept of arousal to describe the intensity aspect of behaviour she did not offer any explanation of a causal relationship between arousal and performance. Her main point with regard to arousal was that it occurred in a continuum from a low point during sleep to a high point during extreme excitement. Of interest in the present investigation is the fact that Duffy included physical exertion as one of the stimuli that may produce a variation in the level of arousal.

Lindsley using recent discoveries in neurophysiology stated that an arousal pattern was discernible on an E.E.G. tracing. For him, the

appearance of the desynchronization of the alpha rhythm was related to high arousal states, which he limited in his early work to a state of emotional arousal.

Hebb previously used the term drive which he saw as an energizer of behaviour but not a guide. He postulated the inverted U principle suggesting that there was an optimal level of drive for effective behaviour. However, in later writings he equates the term drive with arousal. In contrast to Lindsley, he felt that emotion was not synonymous with arousal although he admitted emotion may affect the level of arousal.

Malmo combined each of the three previous theories into one suggesting they appear to lead to the same fundamental concept of arousal, i.e. a moderate level of arousal is required for optimal performance level. He stated that arousal was a function of cortical bombardment by the reticular formation of the brain stem.

French demonstrated the connection of the reticular formation with the cerebral cortex whilst Samuels showed how the reticular formation may be divided into two functional systems, i.e. the brain stem reticular formation and the diffusely projective thalamic nuclei. It was with these two systems that Eysenck suggested was responsible for the personality differences of extraversion and neuroticism.

Finally, Jasper et. al. showed that the reticular formation was particularly sensitive to the hormone epinephrine and therefore its secretion may have an arousing influence on the cortex.

II. Literature Pertaining to the Relationship of Physical Exertion and Performance

During the latter part of last century and the early part of this century, research that was conducted into the relationship between muscular exertion and mental performance showed that mental activity either increased or reduced muscular tension. On the one side Loeb (1886), MacDougal (1896) and Lehmann (1900) concluded that mental effort reduced muscular tension, whilst on the other side Lombard (1887), Fere (1889), Mosso (1894) and Golla (1921) showed that muscular tension increased during mental effort.

Beginning with Bills (1927), the problem was attacked from the opposite direction, namely, tension was induced by various forms of muscular exertion and its effect on mental performance was measured. However, even with this new approach, results were often contradictory.

For example, Bills (1927) found that muscular exertion induced by means of a hand dynamometer improved performance on various mental tasks, such as learning paired associates or adding digits. Freeman (1933), Stauffacher (1937), Brown (1937), Meyer and Noble (1958), Andreassi (1965), and many others, also found evidence for facilitation of mental performance using either the same or similar types of exertion and mental performance as Bills.

On the other hand, Duffy (1932), Block (1936), Shore (1958), Sidowski and Eason (1960) and others, found inhibition of mental performance using the same or similar methods to the researchers previously mentioned. At least one pair of workers, Zartman and Cason (1934), found neither facilitation nor inhibition of mental performance after exertion.

Corcoran (1965) has drawn attention to the difficulties associated with the postulated inverted U relationship between arousal and performance and his explanation may help explain the seemingly divergent results achieved by the above authors.

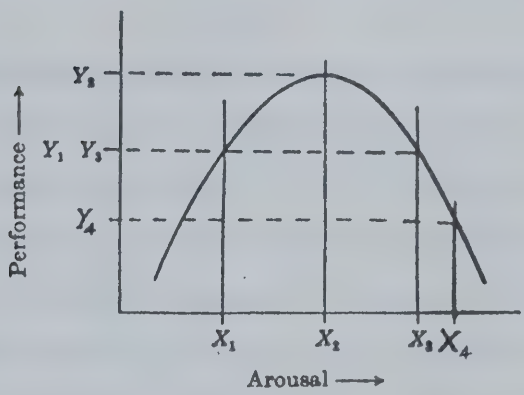

Figure 1: Corcoran's Inverted U

For example, in the above diagram if a person increased in arousal from X_1 to X_2, performance could be shown to be facilitated, i.e. Y_1 to Y_2; if arousal increased from X_1 to X_3 performance would remain the same i.e. Y_1 to Y_3; if arousal increased from X_1 to X_4 performance would be inhibited i.e. Y_1 to Y_4. Or, as Welford (1968 p. 264) explained, "studies which show only a rise or only a fall of performance with increasing arousal, may perhaps be regarded as having explored only one part of the whole range."

A typical experiment which explored the, "whole range", was conducted by Wood and Hokanson (1965). They utilized the essential features of Stauffacher's (1937) experiments of inducing muscular tension by

having the subjects lift weights off the floor (over a series of pulleys) and support them with a minimum of distraction. After determining the subject's maximum strength it was then possible to induce tension at 0, 1/4, 1/2, 3/4 of the maximum, whilst the subject performed a digit symbol substitution task. In addition, heart rate was monitored throughout the test.

The specific hypotheses which were tested (derived primarily from Malmo's (1959) inverted U function model) were, "that performance on a simple learning task would be facilitated with increasing levels of induced tension, up to some maximum point, whereupon it would begin to fall off with further increases in tension. Heart rate, on the other hand as the criterion of arousal, was predicted to increase in a relatively linear fashion throughout the range of induced tension".

The results indicated in the figure following were very similar to those obtained by Stauffacher (1937), Courts (1939) and others, showing the relationship between induced tension and performance.

The performance curve which takes the general shape of the inverted U closely resembles the curve obtained in many earlier studies and in addition, the results were consistent with studies which take account of individual differences among subjects. (Burgess and Hokanson 1964, Hokanson and Burgess 1964, Lovaas 1960).

In addition, heart rate, used as the criterion of arousal, was shown to be an almost linear function as predicted from Malmo's model. However, the authors recognized that caution was necessary in the acceptance of a single autonomic measure as an indicant of arousal as Lacey and Lacey (1958) had shown that this may be questionable.

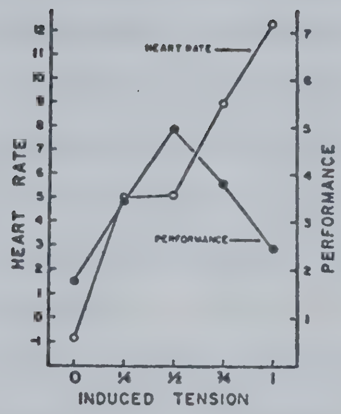

Figure 2: Wood and Hokanson's Inverted U

Another typical experiment that explored the, "whole range" of induced tension was conducted by Marteniuk (1968). However, an important distinction between this and the previous experiment was that motor performance was the criterion of performance. Apart from Courts (1942), Pinneo (1961) and Freeman (1938, 1940) very few investigators were concerned with the effect of induced tension on motor performance, and hence Marteniuk set out to test Duffy's theoretical concept that as muscular tension increased to an optimum, motor performance would reach a maximum, but greater tensions would impair performance.

In this experiment the subject had to press a specially designed reaction lever loaded with an adjustable coil spring, so that the experimenter could vary the force required to push the lever. The force varied through 0-20 lbs. at 5 lb. intervals. The task was a RT-MT

(reaction time, movement time) ball snatch apparatus used by Henry (1951).

The results of the experiment showed that RT improved progressively as tension increased from 0 through 5, 10 and 15 pounds, then reversed the trend and deteriorated when the tension was 20 lbs. Statistical analysis revealed a significant quadratic component as well as showing that the mean RT at 15 pounds of tension was significantly faster than the means at zero and 20 lbs.

However further analysis disclosed that MT became progressively slower as preliminary tension level increased. The conclusions reached by Marteniuk from his investigation were:

(a) facilitation of reaction time through the use of preliminary tension, could be accounted for by an arousal theory of motor performance. (He also offered a possible causal mechanism by suggesting the reticular activating system may be influenced by muscular tension. However, he warned of the possibility that faster reaction times may be caused by a take-up of muscle slack prior to reacting),

(b) inhibition of movement time was probably caused by an increasing shift of attention from the movement phase to the reaction phase of the task, at the higher levels of tension.

Following a series of experiments in which muscular tension was varied systematically along with other variables (e.g. anxiety) a new approach appeared in the research literature during the 1960's. Instead of exertion taken only in the form of static dynamometer tension there appeared forms of dynamic exertion ranging from various exercises (e.g. chins, dips, jumps) to pedalling on a bicycle ergometer, or running

on a treadmill. In each case the experimenter was interested in some form of performance after the exertion. Unfortunately, from the point of view of the present study, many of the studies now to be reviewed have been confounded by the introduction of the variable of physical fitness.

For example, Gutin (1966) wished to test the hypothesis that an increase in physical fitness had a positive effect on the ability of individuals to perform complex mental tasks following physical and mental stress.

Gutin divided a randomly selected sample into control and experimental groups which he subjected to a 45 minute stress period of moderate intensity followed by four tests of verbal comprehension, visual pursuit, verbal reasoning and symbolic reasoning. The stress period consisted of the Indiana Motor Fitness Index II (push-ups, chins, standing broad jump), 30 step-ups on a 20 inch bench for 1 minute, 25 minutes of long addition and subtraction, and another one minute bout of 30 step-ups.

The experimental group then underwent a twelve week development period during which they pursued a course specifically designed to raise their fitness levels. At the end of this period both groups were again tested as before.

Apart from the obvious increase in fitness, the results of the between group comparisons indicated that the hypothesis that an increase in physical fitness had a positive effect on the ability of subjects to perform complex mental tasks following a period of physical and mental stress, was rejected. However, within each group there was evidence

of a moderate relationship between the degree of fitness improvement and mental task ability following stress.

McAdam and Wang's (1967) study was specifically designed to investigate the, "stimulating, exhilarating or physically readying role of exercise", for the performance of a simple mental task. For their experiment they used four treatment groups, one an exercise group, the second had classroom instruction, the third rested and listened to music, while the fourth group took an immediate retest.

Prior to entering the treatment phase each group were administered a symbol substitution test for 10 minutes, which was repeated after the treatment. The exercise consisted of a circulatory promoting run-jog-walk designed to work up a mild sweat but not to fatigue.

The results showed that there were no significant differences in performance following the treatments but there was a trend in favour of the exercise (and rest) group over the other groups. One interesting point in view of the present study, was that the variability of the exercise group was larger than the other three groups.

Following his early interest in this area, Gutin in conjunction with Di Gennaro (1968a) conducted a further experiment into the effect of one minute and five minute step-ups on performance of simple addition. As before, fitness was another variable used as the subjects were divided into two groups, conditioned and unconditioned. Conditioned subjects in this case referred to those students who were enrolled in a developmental class in which step-ups had been used as a regular activity.

Each group was assigned to three treatment groups (a) rest,

(b) 1 minute step-ups and (c) 5 minute step-ups. All subjects took a five minute test of simple addition problems, a task which required both concentration and speed. The addition problems were taken before and after each treatment.

The results showed that among the conditioned subjects the five minute and the rest group did significantly better than the one minute group in speed of addition. There were no other significant differences obtained between treatment groups on speed or accuracy.

Gutin and Di Gennaro felt the results were difficult to explain by reference to the hypothesis of an inverted U shaped curve, which they felt should have been obtained as the level of activation progressed from very low to very high. One possibility they suggested was that for subjects accustomed to exercise, 5 minute step-ups were in the moderate rather than the heavy range of activation. Thus they felt that the 5 minute step-up for the conditioned group was a warm-up rather than a fatiguing exercise. However, they could offer no explanation as to why the 1 minute group should have done the worst of all.

Another interesting feature of their results was that in plotting the accuracy scores of the conditioned and unconditioned subjects, indications were that 5 minute step-ups tended to have a slight positive effect on the conditioned subjects but a slight negative effect upon the unconditioned subjects. Hence they suggested the idea that a specified degree of activity may result in different degrees of activation, depending upon the fitness of the subjects for the activity involved.

A sequel to this study was conducted by the same authors (Gutin and Di Gennaro, 1968b) when they investigated the effect of treadmill run to

exhaustion on performance of long addition.

With each subject acting as his own control both the experimental and control treatments were taken on alternative days. The experimental treatment consisted of a run to exhaustion on a treadmill whilst the control treatment had no exertion. The criterion task taken before and after each treatment consisted of adding single columns of 10 numbers for a period of 4 minutes.

As before, the data was analysed using fitness as a variable, as each subject was divided into a high, medium or low fitness group.

The results showed that numerical accuracy was hindered when it was preceded by heavy muscular exertion whereas numerical speed was not affected significantly. An unexpected finding was that the effect was not especially poor in the first minute after exercise and led the authors to suggest that perhaps exertion had a latent negative effect. Another factor which may have masked the results after the first minute was the great variability, with the high fitness group actually doing better after exertion than the control condition. However the authors stressed that the effect of exertion on addition performance was not conclusively answered, but their study had suggested that speed of addition was not affected by exertion, but accuracy was slightly affected.

Butler's (1968) study was very similar to Gutin's (1966) in that he was concerned with the effect of a ten week physical conditioning program on mental performance after near maximum physical exertion.

Both his control and experimental groups took an initial test on the mental task of symbol substitution and then both groups were

subjected to the conditioning program. Each group was also sub-divided into a low, medium and high group from scores obtained on the American College Testing Programme. The final test was taken by all subjects with the difference that the control group rested before the test, whilst the experimental group performed a near maximum physical exertion task before taking the test.

From the data analyzed Butler drew the following conclusions:

(a) all subjects showed a significant improvement in the simple mental task after the ten week period in which they were involved in a physical conditioning program,

(b) the near maximum physical exertion did not have any significant affect on the performance of the mental task as performed by the three level stratification of low, medium and high group classification, and

(c) the near maximum physical exertion had a stabilizing effect on the performance of the simple mental task of symbol substitution.

Zuercher's (1965) work provides an interesting contrast with the studies previously summarized. Whereas the previous researchers had used various mental tests after exertion, Zuercher was interested in the decrement on vigilance performance after mild exertion.

For his study Zuercher used three experimental conditions, control, verbal stimulation, and mild physical exertion. All subjects were tested randomly four times under each condition on an adaptation of Bakan's (1955) test of vigilance.

The results showed that although the verbal condition did not differ significantly from the control group, the physical exertion group did

differ significantly from the control group, in a favourable direction. However, although there was a slight difference between the verbal and exertion groups, it was not significant.

Zuercher concluded that both conversation and mild exercise had effects in the expected direction resulting in improvement of performance on the vigilance task after deterioration had occurred. He suggested that both conversation and exercise, i.e. both external and internal stimulation, can eliminate vigilance decrement in accordance with the arousal hypothesis. Zuercher felt his results had practical importance for those engaged in monotonous detection tasks.

Since he felt physical exertion was such an important characteristic in sport and many occupations, Stockfelt (1968) set up his research to test mental performance during varied physiological exertion. Again however, he considered fitness as one variable and hence divided his subjects into three groups:

(i) physiologically well trained students,

(ii) physiologically poorly trained students, and

(iii) physiologically poorly trained non-students.

The distinction between students and non students was made on the basis of whether the subject was accustomed or unaccustomed to mental work. Hence the third group were poorly prepared in both aspects.

The physical exertion was obtained on a bicycle ergometer adjusted so that it was possible to obtain exertion levels of 0, 25, 45, 65 and 85 per cent of the maximum for an individual.

The mental task consisted of five series of 40 items of addition and subtraction of five digits, with the score being taken as the number

of correct answers per series.

The results showed that, although not significant, there were differences in performance at the varying levels of exertion, with performance being maximum at the 45 per cent exertion level, and minimum at the 85 per cent exertion level. The results followed an inverted U form for all groups but there were significant differences for the third group, i.e. non students who were physiologically poorly trained. These students gave a significantly poorer performance at the 85 per cent level of exertion than at the lesser levels of exertion. Although both the other groups dropped in performance at the 85 per cent exertion level, it was not significant, nor as low as the third group.

In discussing his results Stockfelt noted the correspondence between his data and "Hebbian" theories concerning the relation between arousal level and performance capacity. He felt that he had found a method of raising arousal levels by physical exertion and suggested, "that further research be undertaken so that we may obtain better knowledge, not only of the relation between physical strength and capacity for mental performance, but also of the psychological complications involved in physical training itself".

Summary

Prior to 1927, research concerned with the relationship between physical exertion and mental performance showed that mental activity either increased or decreased muscular tension. The problem was attacked from the opposite direction commencing with Bills (1927) and research from then on attempted to show the effect of muscular tension upon mental performance. Corcoran (1965) attempted to explain the

seemingly divergent results by reference to his inverted U diagram, in which he suggested that it depended where arousal began and finished in an experiment as to whether performance was facilitated or inhibited. Those experiments, such as Wood and Hokanson (1965) that did explore the whole range of arousal did find facilitation and inhibition in the form of an inverted U.

In the middle 1960's a new series of experiments were conducted using a dynamic form of physical exertion and testing the effect of this exertion on some form of mental performance. Gutin (1966) for example, found that there was a moderate relationship between the degree of fitness improvement and mental task ability following physical and mental stress. McAdam and Wang (1967) found differences in performance in favour of a group who had been physically exerted. Gutin and Di Gennaro (1968b) found that a high fitness group actually did better after exertion than in a control (no exertion) condition. Butler (1968) claimed that near maximum physical exertion had a stabilizing effect on performance of a simple mental task. Zuercher (1965) found that mild exercise had a stabilizing effect on performance of a vigilance task. Finally Stockfelt (1968) showed that a sub-maximal amount of physical exertion improved performance but near maximum exertion inhibited performance. Taken over the whole range of exertion his results fitted the inverted U hypothesis.

It appears then that there is some evidence that physical exertion may influence the level of arousal which in turn effects mental performance.

III. Literature Relating to Extraversion and Neuroticism and Performance

In this section the theoretical background to Eysenck's (1967) theory of personality will be discussed, followed by a description of the Eysenck Personality Inventory. A brief review of the effect of extraversion and neuroticism on performance will then be given.

Following the earlier work of Pavlov (1934), Jung (1921) and Hull (1943), Eysenck (1967) effectively integrated the essential features of these three theories of behaviour to suggest that individuals differ in personality due to the nature of their nervous activity. However, according to Teplov (1964) it was in the first decade of this century that Pavlov first conceived the idea that variations in the strength of the excitatory and inhibitory functions of the nervous system could account for temperamental differences in human personality.

Eysenck developed two broad personality scales, E (extraversion - introversion) and N (neuroticism - stability) which give a behavioural description of personality but did not in themselves give any theory of causation. However he does link the overt personality characteristics with their causal biological source. He believes that behavioural characteristics can be explained at the neural level with the extraversion - introversion scale reflecting the strength of the excitatory and inhibitory functions of the central (cortical) nervous system, and the neuroticism - stability scale reflecting the lability or excitability of the autonomic nervous system.

Recently Eysenck (1967) proposed that the extraversion - introversion

dimension involved the reticular formation (and the associated reticular cortical loop) and the neuroticism - stability dimension was identified with the hypothalamus. (Claridge (1967) has even suggested two sources of personality arousal, sensory reticular arousal and autonomic (hypothalmic) arousal). It is because of the linkage of the reticular formation and the hypothalamus with personality dimensions that Eysenck believes that differing personalities reflect their position on the level of arousal continuum. For example, cortical excitation in response to external stimulation is postulated to be higher in introverts than in extraverts, because he believes introverts possess a weak nervous system. Conversely he postulated that inhibition would be higher in extraverts than introverts. That is, strong excitatory and weak inhibitory potentials typify the introvert, with weak excitatory and strong inhibitory potentials the extravert.

In summarizing the difference between strong and weak nervous systems Gray (1967) states that; (1) the weak nervous system is more sensitive than the strong, (2) it begins to respond at stimulus intensities which are ineffective for the strong nervous system; and throughout the stimulus intensity continuum its responses are closer to the maximum level of responding than the responses of the strong nervous system. According to Gray, Eysenck considers that the dimensions of strength of the nervous system and extraversion - introversion are identical.

Eysenck believes that the cortical supremacy of introverts produces a constraint on their behaviour in accordance with conditioned and learned patterns of responses which leads to the emergence of

particular traits which he has found to characterize introverts; conversely the relative absence of such supremacy leads to an absence of such constraints and thus to the emergence of traits characterizing extraverts.

Concerning the causal basis and neural structure supporting the neuroticism - stability dimension, Eysenck explained it in terms of instability of the autonomic nervous system. He maintained that the autonomic reaction was basically dependent on an individual's constitutional structure which mediates the strength of the sympathetic reaction to incoming stimuli. Although there seem to be characteristic ways in which individuals react to the stimulation of the sympathetic and the way in which control is indicated by the parasympathetic system, Eysenck considers the autonomic nervous system is the most likely basis for individual differences in emotionality.

In summarizing Eysenck's explanation of personality Welford (1968) states that it may be useful to assume that introverts are more chronically aroused than extraverts and that unstable (i.e. neurotic) people tend to become aroused more easily than stable people. If this is so, then Welford expects extraverts to perform many tasks less well than introverts and stable extraverts less well than unstable, (Furneaux (1962) has presented such evidence) and also he expects unstable introverts to do well under easy conditions but liable to breakdown under severe stress. Although he admits the evidence in this area is complex and not easily interpreted, nevertheless some experimental evidence is available to support such hypotheses and some will be presented later.

Eysenck's Personality Inventory (E.P.I.)

The E.P.I. measures personality in terms of two independent

dimensions identified as extraversion - introversion (E) and neuroticism - stability (N). It is a latter development of an earlier measure, the Maudsley Personality Inventory (M.P.I.) (Eysenck 1962) and the E.P.I. correlates sufficiently highly with it to make it almost certain that experimental findings reported for the older instrument will also apply to the newer.

Each of these traits is measured by means of 24 questions selected on the basis of item and factor analysis to which the examinee answers 'Yes' or 'No'. There is also a response distortion or lie scale included in order to detect attempts to falsify responses. The theoretical background and experimental validation of the test has been presented many times, (Eysenck 1947, 1957, 1960, 1967) and many investigations have repeatedly demonstrated the independence of the two dimensions. (Bendig 1970, Burt 1948, Eysenck 1956, Eysenck and Eysenck 1963, Farley 1967).

Eysenck (1968) gives the following brief account of the typical extravert and introvert but suggests that they may be regarded as idealized end points on a continuum to which people may approach to a greater or lesser degree.

EXTRAVERSION - INTROVERSION. High E scores are indicative of extraversion. High scoring individuals tend to be out-going, impulsive and uninhibited, having many social contacts and frequently taking part in group activities .

The typical extravert is sociable, likes parties, has many friends, needs to have people to talk to, and does not like reading or studying by himself. He craves excitement, takes chances, often sticks his neck out, acts on the spur of the moment and is generally an impulsive

individual. He is fond of practical jokes, always has a ready answer, optimistic, and likes to 'laugh and be merry. He prefers to keep moving and doing things, tends to be aggressive and to lose his temper quickly. His feelings are not kept under tight control, and he is not always a reliable person.

The typical introvert is a quiet retiring sort of person, introspective, fond of books rather than people; he is reserved and distant except to intimate friends. He tends to plan ahead, looks before he leaps and distrusts the impulse of the moment. He does not like excitement, takes matters of everyday life with proper seriousness, and likes a well ordered mode of life. He keeps his feelings under close control, seldom behaves in an aggressive manner, and does not lose his temper easily. He is reliable, somewhat pessimistic, and places great value on ethical standards.

In a similar fashion Eysenck (1968) reports the following description of a person high on the neuroticism scale.

NEUROTICISM. High N scores are indicative of emotional lability and over-reactivity. High scoring individuals tend to be emotionally over-responsive and to have difficulties in returning to a normal state after emotional experiences. Such individuals frequently complain of vague somatic upsets of a minor kind such as headaches, digestive troubles, insomnia, backaches, etc. and also report many worries, anxieties and other disagreeable emotional feelings. Such individuals are predisposed to develop neurotic disorders under stress, but such predispositions should not be confused with actual neurotic breakdown; a person may have quite high scores on N while yet functioning adequately in work, sex,

family and society spheres.

Eysenck (1968) makes it clear that the above descriptive behavioural patterns refer to personality in its phenotypic aspect, but they are based upon the constitutional or genotypic aspect mentioned earlier.

From this present theory Eysenck (1968) makes predictions which experimentation appears to support. For example, he states that introverts show better performance on vigilance tests, have longer after images, preserve visual fixation better, show less satiation, have greater tolerance for sensory deprivation but less tolerance for physical pain, and show better performance when a measure is made of their critical flicker fusion thresholds. Some of the experimentation which supports this theory will now be offered in greater detail.

According to Eysenck (1967) he expects extraverts to be better at recall in short term intervals and conversely that introverts would show better serial learning and digit span memory when the interval between learning and testing was relatively long. Howarth and Eysenck's (1968) results were consistent with this expectation when they found that extraverts were superior in paired associate recall at short term intervals but inferior at long term intervals. They felt their results supported the theory that extraverts possess higher thresholds of arousal and when combined with Walker's (1963) hypothesis that retention is a function of consolidation of traces, and that high arousal results in slower but more permanent consolidation, it follows that high arousal subjects (introverts) would have poor immediate recall but superior delayed recall. They concluded that this experiment showed that extraverts behaved as though they have lower arousal.

However, Howarth (1963) had previously found the reverse position when considering the time span of digit recognition. He agreed that his results were surprising in that the ability to hold the information over a longer period of time was greater in extraverts than in introverts. Nevertheless in the same experiment he did find that extraverts were superior in breath holding, showed longer leg persistance, greater variability in line reproduction, a tendency to under-estimation in time judgement but were inferior in arithmetic computation under slow set change conditions. He did feel that the majority of his findings (that is apart from the time span of digit recognition) were in the direction to support Eysenck.

When performance was measured by learning paired associates McLaughlin and Eysenck (1967) found differences between the two personality variables of extraversion and neuroticism.

In their experiment they divided subjects into four personality groups by dividing E and N into high and low scorers. (i.e. the four groups were stable extraverts S.I.; neurotic extraverts N.E.; stable introverts S.I.; and neurotic introverts N.I.). Using standard tests for paired associate learning the subjects learned lists to a criterion of one errorless trial. Two separate experiments were conducted, one using an easy list containing words of high meaningfulness, the other a difficult list containing words of low similarity.

The results of both experiments were consistent with Eysenck's theories, namely that stable-extraverts and the neurotic-introverts would be below and above, respectively, the optimum performance in learning the easy list. In learning the difficult list it was

predicted that the optimum level for performance would shift towards the low arousal group, and it was found that the stable extraverts were best and the neurotic introverts significantly poorer. No prediction had been made between the intermediate personality groups and hence the stable introverts and neurotic extraverts did not differ significantly on either list.

McLaughlin and Eysenck explained their results in terms of the higher cortical arousal in introverts which facilitated consolidation. Moderate anxiety which they felt was determined by the relationship of neuroticism and extraversion-introversion was shown to facilitate learning the difficult list. Figure 3 shows McLaughlin and Eysenck's inverted U's for both the easy and difficult lists.

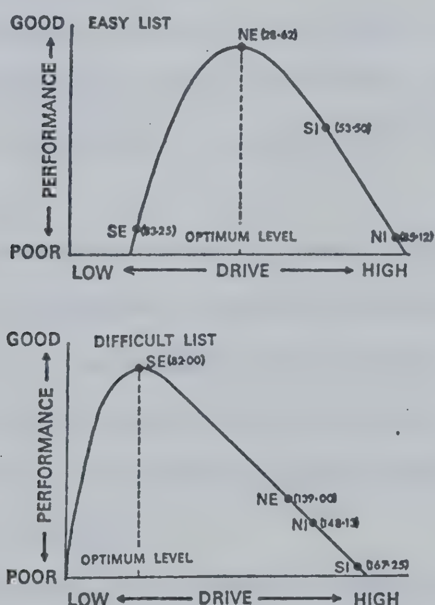

Figure 3: McLaughlin and Eysenck's Inverted U's

The aforementioned experiments are but a small sample of studies mentioned by Eysenck (1970) in his recent three volume publication on Readings in Extraversion-Introversion. Similar experimental research, showing differences in performance by subjects with varying dimensions on the neuroticism scale have been fully documented by Claridge (1967).

Summary

Eysenck has proposed two personality dimensions, namely extraversion-introversion and neuroticism-stability. He believes that the differences between the various behavioural characteristics of each personality type can be explained at the neural level. He equates the extraversion dimension with the excitation of the reticular formation and the neuroticism dimension with the hypothalamus.

Welford summarizes the position by suggesting that it may be useful to assume that introverts are more chronically aroused than extraverts and that neurotic people tend to become aroused more easily than stable people.

Eysenck's Personality Inventory gives a measure of personality in terms of the two independent dimensions of extraversion and neuroticism which he states may be regarded as end points on a continuum to which people may approach to a greater or lesser degree. He also gives a full account of the typical behavioural patterns expected from a person who approaches these end points.

Both Eysenck and Claridge present a great deal of research to show the differences in performance of the various personality types and some of this research has been discussed.

Hence if the level of arousal is influenced by different personality dimensions, then differences in the level of arousal produced by physical exertion could be expected from the various personality types.

CHAPTER III

METHODS AND PROCEDURES

I. Design Considerations

The design of the experiment, to be detailed later, was such that a number of factors were considered in order to eliminate many of the problems mentioned by other workers in the literature survey. Apart from choosing an adequate experimental design, it was also necessary to consider choosing: (i) a suitable test of mental performance, (ii) an appropriate method of physical exertion and (iii) a valid and reliable test of personality.

Criteria for Selection of the Mental Task

The first consideration was that the mental task must be demanding but not one that previous experience would materially assist or inhibit. If possible the task should be a departure from routine methods of solution (e.g. addition of digits) or problems which could be solved by methods acquired from experience (e.g. mathematical induction). It was also essential to obtain a task in which learning, during performance, did not greatly affect performance with successive repetitions of the task. A final criterion was that the task should be readily quantifiable and in such units that it was possible to discriminate between small fluctuations in performance.

Moray (1970) stated that one of the most important subdivisions of the concept of attention was that of mental concentration. Wittenhorn (1943) had previously claimed that tests of attention which are relatively

free from the influence of such things as practice effect, rote learning, vocabulary size etc. are tests which are heavily loaded with a factor identified as mental concentration. An example of such a test, he suggested, was one in which the listener was required to identify groups of three digits which were presented at the rate of one per second. Following earlier work by Bornemann (1942) and Broadbent (1956), Brown (1962) used the Brown and Poulton (1961) test of attention which they claimed was a test of mental concentration. The test (to be described later) required continuous attention to auditory signals (digits) from a tape recorder and involved memory spans of a few seconds, and the identification of groups of three digits. Since this test relied heavily on short term memory it was considered to be a task demanding the 'highest level' of mental performance (Welford, 1968, p. 266). Also, since this same test had been successfully used in previous investigations (Davey 1968, 1972a, 1972b) and met each of the above criteria, it was chosen for the present study.

Because the Brown and Poulton test relied so heavily on short term memory as well as the ability to process information, it was felt necessary to have another task which measured short term memory exclusively. The digit span recall test used by Wechsler (1944) was chosen because as Patterson (1953) stated, the test involved immediate memory for digits and is affected by receptivity and readiness of response and thus involved attention.

The use of these two tests should then make it possible to identify whether any fluctuation in the Brown and Poulton task was due to short term memory or processing capacity per se.

Criteria for Selection of the Physical Task

The second consideration was that the physical exertion must be such that the amount of work done by the subjects must be measurable and of such a nature that it could be continued for varying lengths of time (e.g. from 15 seconds up to 6 minutes). For preference, the exertion should be taken in such a manner that the change from the mental to the physical task and vice versa, should not interfere with the preceding task. Since a constant torque bicycle ergometer satisfied these criteria it was decided to use this method of physical exertion.

Criteria for Selection of Personality Test

The third consideration was that a valid and reliable measure of the personality traits of extraversion-introversion and neuroticism-stability was needed. As Eysenck (1966) has repeatedly pointed out, individual differences in personality may account for large amounts of variance which in many cases is relegated to the error term unless account is taken of these individual differences. According to Eysenck (1969), the Eysenck Personality Inventory (E.P.I.), which measures the two independent dimensions of personality extraversion-introversion and neuroticism-stability, accounts for most of the variance in the personality domain.

Eysenck and Eysenck (1968) have stated that the test retest reliability of the E.P.I. ranges between .84 and .94 which they consider quite satisfactory. The test has also high validity correlations with similar tests, including .72 on the extraversion scale with the Guilford (1940) Rhathymia scale, and .92 on the neuroticism scale with the Cycloid

Disposition scale. Many other reliability and validity coefficients are given in the E.P.I. manual together with the factorial validity with each of the factors it purports to measure.

Hence the E.P.I. was selected as an appropriate measure of the personality traits of extraversion and neuroticism. One additional benefit of the E.P.I. was that it has been used many times in research concerned with arousal and thus makes available valuable comparisons.

II. Selection of Experimental Subjects

During previous pilot studies (Davey 1968, 1972a, 1972b) there was some indication that students taking mathematics or statistics at university level were able to perform well on the Brown and Poulton test. For example, some students were able to score as high as 20/26 before exertion and although they improved after exertion, such a high initial score did not allow the opportunity for significant improvement. (It did, of course, give the opportunity for significant deterioration in performance.) However, some non-mathematicians were also able to obtain high scores, so performing well on this test was not necessarily restricted to mathematicians.

Because of the nature of the experiment which included some heavy physical exertion, subjects were required who were prepared to endure some physical fatigue. For this reason, students taking physical education at the University of Melbourne were chosen to act as subjects. Also, these subjects were readily accessible to the experimental room and were available to the experimenter at convenient times.

The subjects chosen consisted of both males and females, whose average age was 19 years, ranging from 18 to 21 years. Previous investigations had shown these students to be capable of the physical exertion required in the experiment.

It was considered advantageous to use only subjects unfamiliar with the experimental techniques and who had not been used as subjects in similar experiments previously. No remuneration or reward was offered to the subjects although all appeared keen to participate in the experiment. Few questions were asked as to the nature of the experiment, but each subject was informed that the experiment would involve two separate mental tasks and the pedalling of a bicycle ergometer. All subjects were informed that the results of the experiment would be made known to them when the experiment had been completed.

III. Experimental Design

The experimental design was a 2 x 2 x 6 factorial design with repeated measures on the last factor. Factor A consisted of two levels of personality, extraversion and introversion, whilst factor B also had two levels of personality, neuroticism and stability. Factor C, the independent variable, consisted of 6 levels, each one being a different level of physical exertion to which each student was subjected. The dependent variable was the scores on the mental performance tasks. Each of the three factors was a fixed factor (Winer 1962, p. 143).

Twenty subjects were chosen in each of the 4 categories (i.e. 2 levels each of factor A and B) making a total of 80 subjects. The

determination of the sample size was obtained by the procedures outlined by Winer (1962, p. 104).

IV. Apparatus

The two main pieces of apparatus were the tape recorder and the bicycle ergometer which are described below.

(a) Tape Recorder

The Brown and Poulton test (described shortly) was recorded on a Toshiba solid state tape recorder, an instrument so arranged that the subject could hear the test through earphones whilst the experimenter could hear the test through the normal speaker. The volume was adjustable for the convenience of the experimental subject.

(b) Bicycle Ergometer

The bicycle used was the Tritt[1] constant torque bicycle ergometer, which was so constructed that with a given torque setting and a constant speed, (seen on the speedometer in revolutions per minute) the required amount of work done in a given time was achieved when a certain number appeared on the revolution counter. This could be seen by both experimenter and subject.

Brown and Poulton Test

In this test the subject heard through earphones from a tape recorder, a continuous series of digits taken from the range 1-9 at one second

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[1]The bicycle ergometer was designed and built for the Australian Sports Medicine Federation by B.H. Tritt, Mechanical Engineering Department, University of Melbourne.

intervals (Hind, 1968). The series was formulated from random numbers with the restraint that no numbers occurred twice in succession. The task was to detect a sequence of digits which occurred in the order 'odd-even-odd', and to respond by saying 'Yes' before the next digit was presented. (Directions for the test and score sheet are given in Appendices E and G.) The score was the number of series correctly identified.

Short Term Memory Test

In this test the subject heard a series of digits through the earphones, read by the experimenter, and was asked to repeat the digits upon completion. Initially the Wechsler test was used, with additional tests being constructed by the experimenter using the same principles; i.e. no number is repeated twice in the same series, with the exception of the ten digits, and in this case the repeated number was more than two digits apart.

In the test if the subject repeated the series correctly then he continued with the next higher series. If the subject failed then he was given a second trial on a series of equal length. The test was discontinued after the subject had failed both trials of a given series. The score was the highest number of digits repeated without error in either of the two trials.

Heart Rate

Heart rate was taken from a thumb cuff and connected to a direct reading heart rate meter.

V. Data Recording

Short Term Memory Test

A recording sheet (see Appendix F) with the digits in the correct order of presentation was used for each subject in the experiment. Each time the subject repeated the digits correctly the experimenter placed a check mark in the appropriate column. An incorrect response was recorded by a cross. The score was the highest number of digits with a check mark which immediately preceded the final two crosses.

Brown and Poulton Test

A recording sheet (see Appendix G) with the random numbers in the correct sequence was used for each subject. Each time the subject said 'yes' to a correctly identified series a check mark was placed after the last number spoken from the tape recorder. Since on the recording sheet an asterisk had been placed after each 'odd-even-odd' sequence, a correct score was obtained each time a check mark coincided with an asterisk. The final score was the total number of correct check marks.

Physical Exertion

As a check on the amount of work done by the subject the time from a stop watch was recorded as well as the number of revolutions on the revolution counter. Heart rate was read off the heart rate meter and recorded on the score sheet immediately upon cessation of the physical exertion.

VI. Procedure

Prior to the testing period in the laboratory all subjects had taken the Eysenck Personality Inventory and there was no indication from the experimenter that the personality test and the following experiment were in any way related. The subjects were kept naive as to the purpose of the experiment and were told only what appeared on the instruction sheet.

When the subject arrived at the laboratory he/she was greeted cordially and asked to sit on the bicycle ergometer, whilst the seat and pedals were adjusted for personal comfort. The subject was then handed a briefing sheet (see Appendix E) and asked to follow the instructions while the information was read. Any questions that were asked were answered if possible. Most subjects repeated the procedure to the experimenter who confirmed or corrected them. The earphones and the thumb cuff (pulse meter) were then adjusted to suit the subject and the experiment began. The procedure was as follows:

(a) Mental task: short term memory test followed by the Brown and Poulton test (approximately 2.5 minutes). The first mental test was considered as a trial run in order to familiarize the subject with the two tests.

(b) Treatment A (2 minutes): Treatment A consisted of a 2 minute rest period in which the subject remained on the bicycle ergometer and was encouraged to relax.

(c) Mental task.

(d) Treatment B (2 minutes): Treatment B consisted of resting for

1-3/4 minutes and then pedalling the bicycle ergometer for 15 seconds (3,000 ft. lb.).

(e) Mental task.

(f) Treatment C (2 minutes): Treatment C consisted of resting for 1-1/2 minutes and then pedalling the bicycle ergometer for 30 seconds (6,000 ft. lb.).

(g) Mental task.

(h) Treatment D: Treatment D consisted of pedalling the bicycle ergometer for 2 minutes (20,000 ft. lb.).

(i) Mental task.

(j) Treatment E: Treatment E consisted of pedalling the bicycle ergometer for 4 minutes (30,000 ft. lb.).

(k) Mental task.

(l) Treatment F: Treatment F consisted of pedalling the bicycle ergometer for 6 minutes (40,000 ft. lb.).

(m) Mental task.

CHAPTER IV

RESULTS

This chapter has been organized into three main sections. Section I deals with the descriptive statistics of the Eysenck Personality Inventory (E.P.I.); Section II is concerned with analyzing the effects of physical exertion, and the relationships between the Eysenck personality variables on the short term memory test; and Section III is concerned with analyzing the effects of physical exertion and the relationships between the Eysenck personality variables on the Brown and Poulton test.

I. The Eysenck Personality Inventory

One hundred and fifty subjects were given the E.P.I. From this group 80 subjects whose scores were in the extremes on each of the two dimensions of extraversion and neuroticism were selected to participate in the study. Each of the four categories, stable extraversion, neutotic extraversion, stable introversion and neurotic introversion contained 20 subjects.

Table 1 shows the mean raw score for extraversion to be 12.9 whilst the mean raw score for neuroticism was 10.5. From the manual of the E.P.I. these raw scores place the subjects at the 60th percentile for both extraversion and introversion on norms taken from American college students. Figure 4 presents a graphical representation of these scores whilst the individual scores are presented in Appendix B.

TABLE 1

MEANS, STANDARD DEVIATIONS AND PERCENTILES FOR 80 SUBJECTS

	Extraversion	Neuroticism
Mean	12.9	10.5
Standard Deviation	1.9	2.5
Percentile	60	60

Table 2 presents these scores in each of the four categories, stable extraversion, neurotic extraversion, stable introversion and neurotic introversion.

TABLE 2

MEANS, STANDARD DEVIATIONS AND PERCENTILES

FOR SUBJECTS BY PERSONALITY CATEGORY

	Stable Extraversion		Neurotic Extraversion		Stable Introversion		Neurotic Introversion	
	Extra-version	Neurot-icism	Extra-version	Neurot-icism	Extra-version	Neurot-icism	Extra-version	Neurot-icism
Mean	16.8	5.1	16.8	15.8	9.4	6.2	8.8	15.2
Standard Deviation	2.2	2.2	2.4	2.4	1.4	2.6	1.6	2.8
Percentile	90	21	90	90	30	28	25	88

This shows that the mean score for stable extraversion is at the 90th percentile for extraversion and the 21st percentile for neuroticism which according to Eysenck and Eysenck (1968) respectively depicts a person

above and below average in the trait measured. This also applies to the extraversion and neuroticism scores for neurotic extraversion, stable introversion and neurotic introversion, although as can be seen from Figure 4 the mean score for stable introversion is not as extreme a score as each of the other three categories. This can be explained by the fact that the mean score for extraversion and neuroticism for the original population from which the sample was chosen was at the 64th and 56th percentile respectively. As can be seen from Figure 4 almost half the subjects in stable introversion could be classified as borderline cases in this particular category.

II. Short Term Memory

The results for all subjects of the short term memory test immediately following the six periods of exertion are given in Table 3.

TABLE 3

SHORT TERM MEMORY SCORES AFTER EXERTION FOR 80 SUBJECTS

Minutes Exertion	Mean	Standard Deviation
0	7.2	0.92
1/4	7.0	0.63
1/2	7.1	0.76
2	7.1	0.83
4	6.8	0.60
6	6.5	0.92

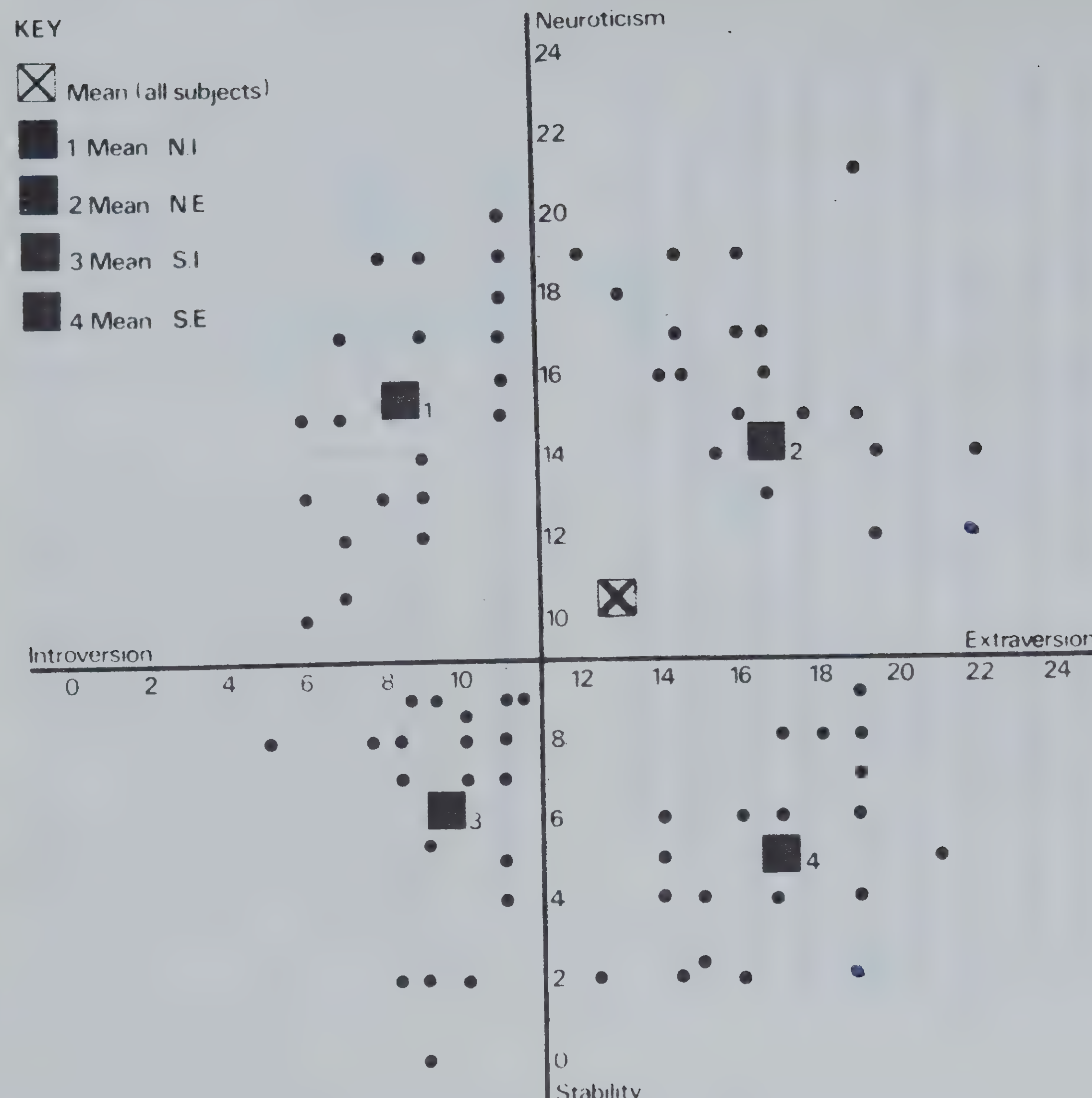


Figure 4 Graphic Presentation of Subjects on Dimensions of Extraversion Introversion and Neuroticism-Stability

This shows that the mean score on the short term memory test remained relatively constant during 0, 1/4, 1/2 and 2 minutes exertion, i.e. the mean score ranged only from 7.0 to 7.2. It was not until after 4 or 6 minutes exertion that the score dropped to below 7.

Table 4 examines the short term memory scores for each of the four personality divisions, stable extraversion, neurotic extraversion, stable introversion and neurotic introversion. This shows that the mean scores for the neurotic extraversion group were slightly higher than each of the other three groups both before and after exertion.

Figures 5, 6 and 7 present a graphical representation of these scores whilst Appendix C contains the individual scores.

TABLE 4

SHORT TERM MEMORY SCORES AFTER EXERTION BY PERSONALITY

Minutes Exertion	Total	Extraversion		Introversion	
		S	N	S	N
0	7.2	7.1	7.4	7.0	7.1
1/4	7.0	7.0	7.2	6.9	6.9
1/2	7.1	7.2	7.1	7.1	7.0
2	7.1	7.0	7.2	7.1	7.1
4	6.8	6.8	7.0	6.6	6.8
6	6.5	6.6	6.9	6.1	6.4

A 2 x 2 x 6 analysis of variance was calculated and is summarized in Table 5. (Full details are available in Appendix C).

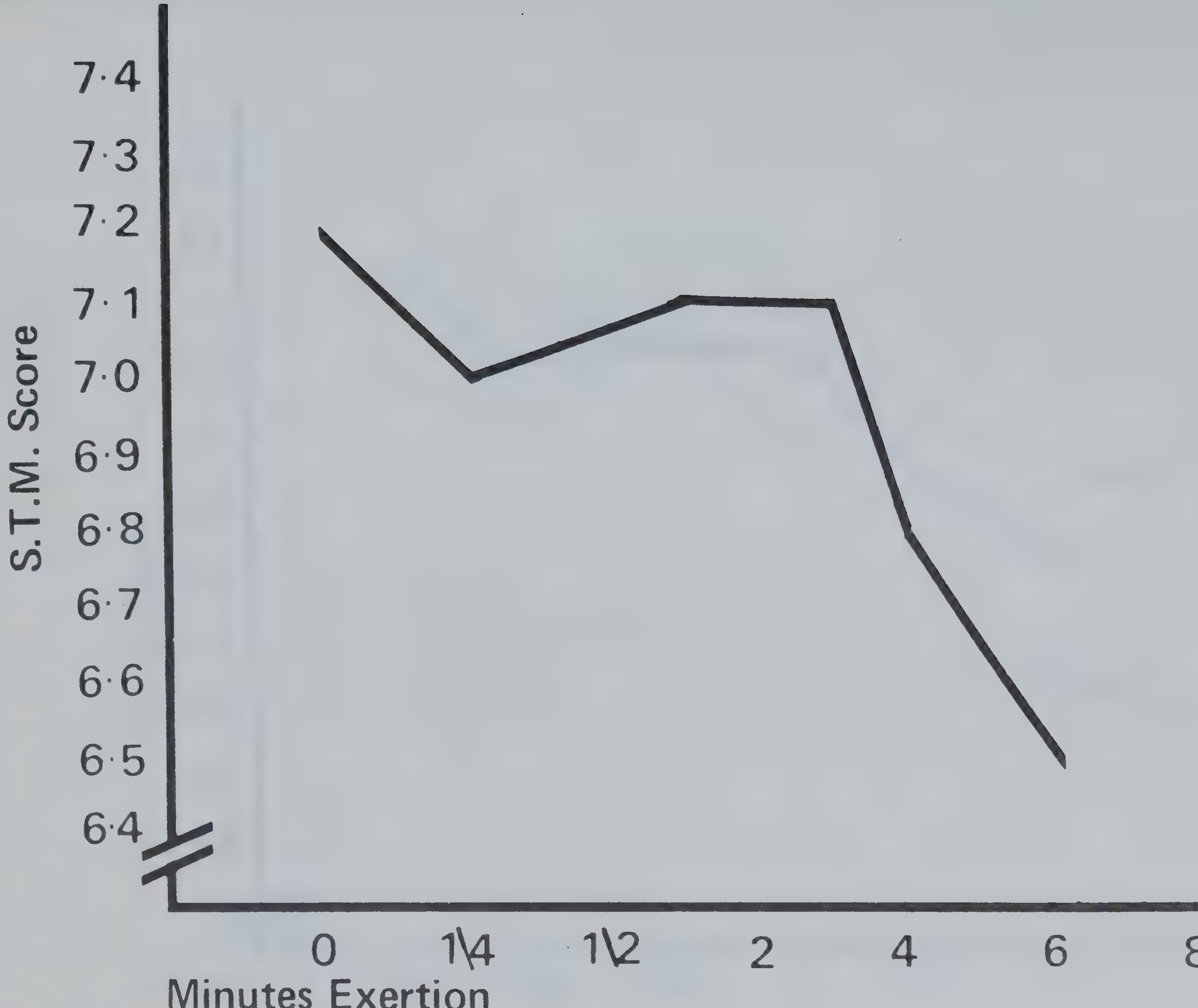


Figure 5 Short term memory score after exertion. (N=80)

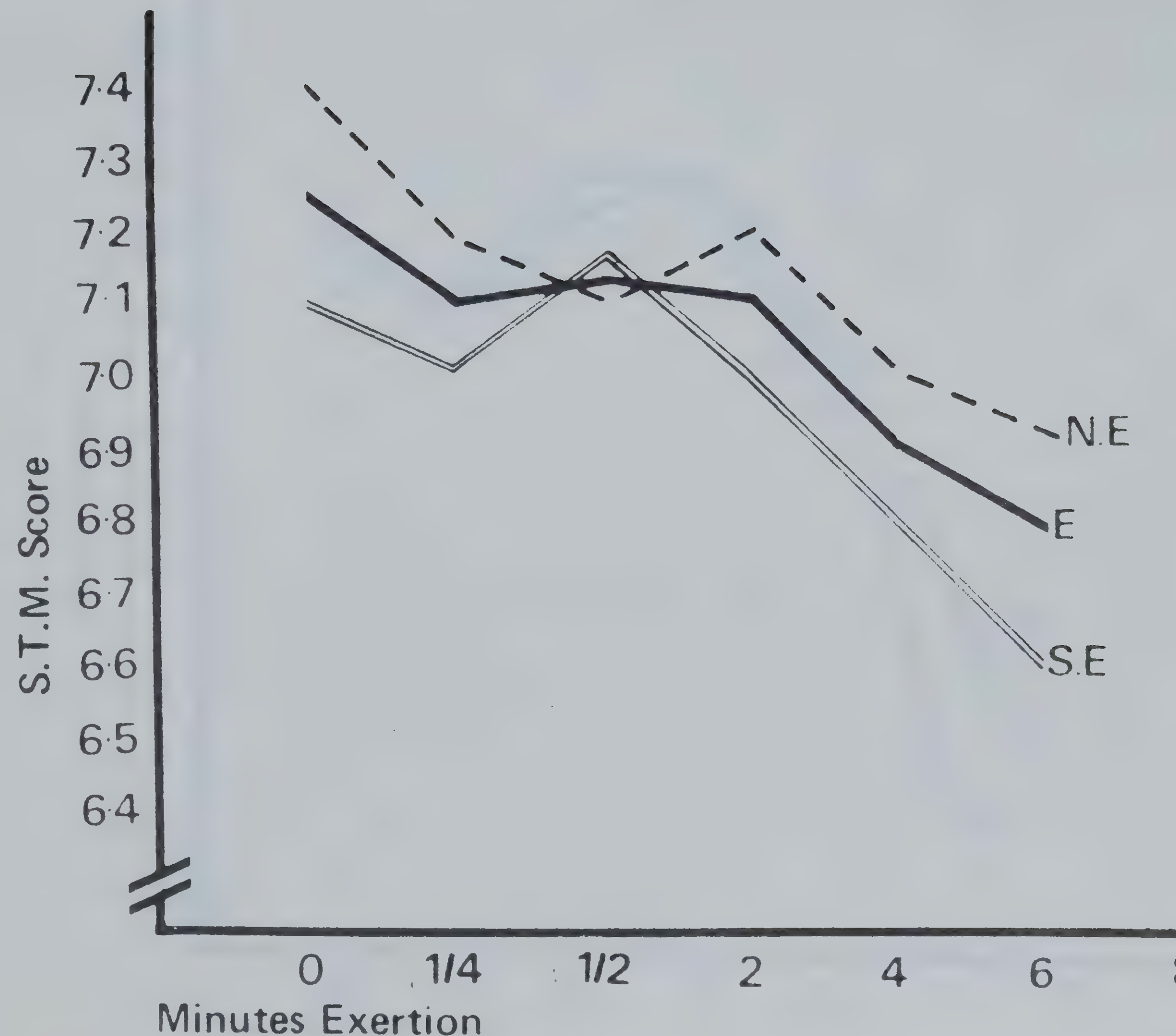


Figure 6 Short term memory score after exertion.
(Extraverts. N=40)

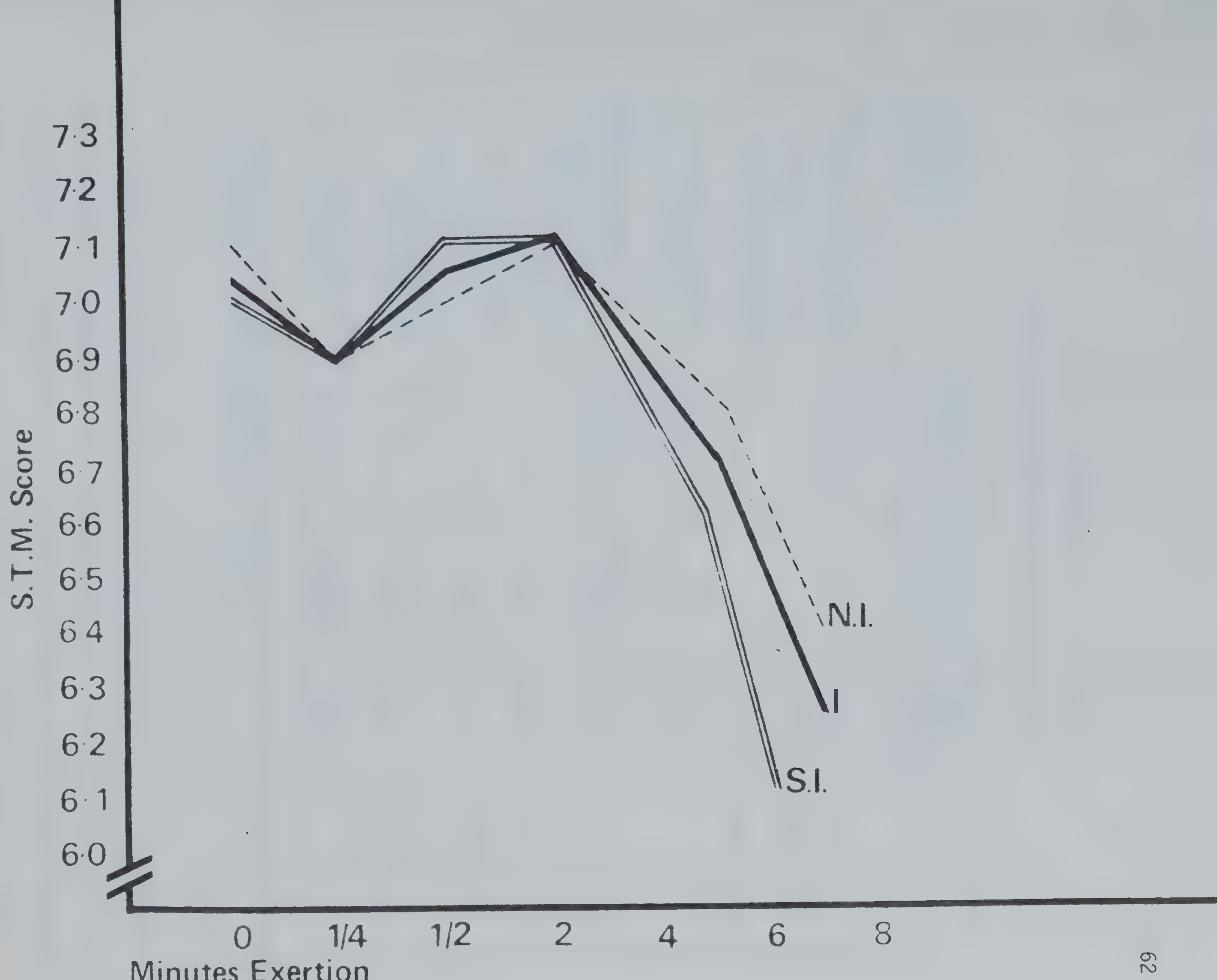


Figure 7 Short term memory score after exertion.
(Introverts N=40)

TABLE 5

ANALYSIS OF VARIANCE ON S.T.M. TEST

Source of Variation	Sum of Squares	Degrees of Freedom*	Mean Square	F	p
Between Subjects	244.03	79			
(A) Extraversion	4.80	1	4.80	1.54	N.S.
(B) Neuroticism	2.13	1	2.13	0.68	N.S.
(AB) Extraversion/ Neuroticism	0.30	1	0.30	0.09	N.S.
Subjects Within Groups	236.8	76	3.11		
Within Subjects	160.34	400			
(C) Exertion	24.97	5(1)	4.99	14.67	<.01
(AC) Extraversion/ Exertion	2.80	5(1)	0.56	1.64	N.S.
(BC) Neuroticism/ Exertion	1.87	5(1)	0.37	1.08	N.S.
(ABC) Extraversion/ Neuroticism/ Exertion	0.30	5(1)	0.06	1.17	N.S.
C x Subjects Within Groups	130.4	380(76)	0.34		

* Numbers in brackets indicate the degrees of freedom for the Greenhouse and Geisser (1959) Conservative F test.

Table 5 shows that there were no statistically significant differences between subjects in short term memory scores on the basis of extraversion, or introversion, or interaction between these two personality traits. However there was a statistically significant ($p < .01$) difference in the short term memory scores after exertion. Table 6 shows the Newman Keuls test on the difference between all pairs of ordered

means on the short term memory test scores after exertion.

TABLE 6

NEWMAN KEULS TEST ON S.T.M. TEST

MAIN EFFECTS OF FACTOR C

Minutes Exertion	6	4	1/4	1/2	2	0
Factor	C_6	C_5	C_2	C_3	C_4	C_1
Ordered Means	6.5	6.8	7.0	7.1	7.1	7.2
Differences Between Pairs C_6	-	0.3	0.5	0.6	0.6	0.7
C_5		-	0.2	0.3	0.3	0.4
C_2			-	0.1	0.1	0.2
C_3				-	0.0	0.1
C_4					-	0.1
C_1						-
$S\bar{c}$ = .09		2	3	4	5	6
.95(r,380)		2.77	3.31	3.63	3.86	4.03
$S\bar{c}$ .95(r,380)		0.25	0.29	0.32	0.32	0.36
	C_6	C_5	C_2	C_3	C_4	C_1
C_6	-	*	*	*	*	*
C_5		-	-	*	*	*
C_2			-	-	-	-
C_3				-	-	-
C_4					-	-
C_1						-

The Newman Keuls test shows that the short term memory test scores dropped significantly after 4 and 6 minutes exertion.

III. Brown and Poulton

The mean and standard deviation scores for the 80 subjects on the Brown and Poulton test after the six periods of exertion are presented in Table 7.

TABLE 7

MEANS AND STANDARD DEVIATIONS ON BROWN AND POULTON TEST AFTER EXERTION FOR 80 SUBJECTS

Minutes Exertion	0	1/4	1/2	2	4	6
Mean	12.2	12.0	17.8	19.5	17.0	11.6
Standard Deviation	2.9	3.3	3.6	3.0	3.0	3.0

This shows that the mean score on the Brown and Poulton test deteriorated slightly from 0 to 1/4 minute exertion and thereafter rose after 1/2 and 2 minutes exertion with a subsequent falling off in performance after 4 and 6 minutes exertion.

Tables 8A, B, and C presents the mean score on the Brown and Poulton test in each of the following categories: extraversion-introversion; neuroticism-stability; stable extraversion-neurotic extraversion, and stable introversion-neurotic introversion.

TABLE 8A

MEAN SCORE ON BROWN AND POULTON TEST

AFTER EXERTION BY PERSONALITY

Exertion	0	1/4	1/2	2	4	6
Extraversion	12.3	11.8	17.4	20.1	18.5	12.2
Introversion	12.1	12.2	18.2	19.2	15.5	11.0

TABLE 8B

MEAN SCORE ON BROWN AND POULTON TEST

AFTER EXERTION BY PERSONALITY

Exertion	0	1/4	1/2	2	4	6
Stability	12.1	12.0	17.6	19.6	17.5	12.1
Neuroticism	12.2	11.9	18.0	19.7	16.6	11.0

TABLE 8C

MEAN SCORE ON BROWN AND POULTON TEST

AFTER EXERTION BY PERSONALITY

Exertion	0	1/4	1/2	2	4	6
Extraversion						
Stability	12.3	11.5	17.2	19.8	19.5	13.2
Neuroticism	12.3	12.1	17.6	20.4	17.5	11.2
Introversion						
Stability	12.0	12.6	18.0	19.4	15.5	11.1
Neuroticism	12.2	11.8	18.4	19.0	15.7	10.9

Again a 2 x 2 x 6 analysis of variance was calculated and is summarized in Table 9 with the full details in Appendix D. Table 9 shows that the main effects for factors A and B (extraversion and neuroticism) and the interaction for AB (extraversion/neuroticism) are not statistically significant. However, the main effects of factor C (exertion) and the interaction effects for AC (extraversion/exertion) are statistically significant ($p < .01$). Also the interaction effects for BC (neuroticism/exertion) and ABC (extraversion/neuroticism/exertion) are statistically significant ($p < .05$). Since the main effect of C and the interaction effect for ABC were significant, a test for significance between all possible pairs of means on factor C and ABC was calculated using the Newman Keuls procedure. Tables 10 and 11 summarizes these calculations.

Table 10 shows that there were no statistically significant differences between the means for exertion in C_1, C_2 and C_6 (0, 1/4 and 6 minutes exertion) but there were statistically significant differences between these three means and the means for exertion in C_3, C_4 and C_5 (1/2, 2 and 4 minutes exertion).

Table 11 shows that there were no statistically significant differences between the means for stable introversion and neurotic introversion, and neurotic introversion and neurotic extraversion, but there were statistically significant differences between neurotic extraversion and stable introversion, and stable extraversion and stable introversion, neurotic introversion and neurotic extraversion.

Figures 8, 9, 10, 11 and 12 graphically present the material contained in Tables 7, 8A, 8B and 8C.

TABLE 9

ANALYSIS OF VARIANCE ON BROWN AND POULTON TEST

Source of Variation	Sum of Squares	Degrees of Freedom*	Mean Square	F	p
Between Subjects	4205.1	79	53.3	0.97	N.S.
(A) Extraversion	53.3	1	7.5	0.13	N.S.
(B) Neuroticism	7.5	1	2.7	0.04	N.S.
(AB) Extraversion/ Neuroticism	2.7	1	54.4		
Subjects Within Groups	4141.6	76			
Within Subjects	5827.7	400			
(C) Exertion	4964.0	5(1)	992.8	661.86	<.01
(AC) Extraversion/ Exertion	176.7	5(1)	35.3	23.53	<.01
(BC) Neuroticism/ Exertion	36.7	5(1)	7.3	4.86	<.05
(ABC) Extraversion/ Neuroticism/ Exertion	52.7	5(1)	10.5	7.00	<.05
Exertion x Subjects Within Groups	597.6	380(76)	1.5		

* Numbers in brackets indicate the degrees of freedom for the Greenhouse and Geisser (1959) Conservative F test.

TABLE 10

NEWMAN KEULS TEST ON BROWN AND POULTON TEST

MAIN EFFECTS OF FACTOR C

Minutes Exertion	6	1/4	0	4	1/2	2
Factor	C_6	C_2	C_1	C_5	C_3	C_4
Ordered Means	11.6	12.0	12.2	17.0	17.8	19.5
C_6	-	0.4	0.6	5.4	6.2	7.9
Differences C_2		-	0.2	5.0	5.8	7.5
Between C_1			-	4.8	5.6	7.3
Pairs C_5				-	0.8	2.5
C_3					-	1.7
C_4						-
$S_{\bar{C}} = .19$	r =	2	3	4	5	6
.95(r,380)		2.77	3.31	3.63	3.86	4.03
$S_{\bar{C}}$ .95(r,380)		0.52	0.62	0.68	0.73	0.76
	C_6	C_2	C_1	C_5	C_3	C_4
C_6	-	-	-	*	*	*
C_2		-	-	*	*	*
C_1			-	*	*	*
C_5				-	*	*
C_3					-	*
C_4						-

TABLE 11

NEWMAN KEULS TEST ON BROWN AND POULTON TEST

INTERACTION EFFECTS OF ABC

SIMPLE MAIN EFFECTS OF C_5

	Stable Introversion	Neurotic Introversion	Neurotic Extraversion	Stable Extraversion
Ordered Means	15.5	15.7	17.5	19.5
Stable Introversion	-	0.2	2.0	4.0
Neurotic Introversion		-	1.8	3.8
Neurotic Extraversion			-	2.0
Stable Extraversion				-
	$S_{\overline{A}}$ = .67	r = 2	3	4
		2.86	3.44	3.79
		1.92	2.30	2.53
	Stable Introversion	Neurotic Introversion	Neurotic Extraversion	Stable Extraversion
Stable Introversion	-	-	*	*
Neurotic Introversion		-	-	*
Neurotic Extraversion			-	*
Stable Extraversion				-

Hypotheses

On the basis of the review of literature in Chapter II and the objective of the study the following null hypotheses were set up:

(a) H_1: There would be no effect in mental performance after various amounts of physical exertion.

(b) H_2: There would be no difference between the personality divisions in mental performance after various amounts of physical exertion.

As a result of the analysis of variance in Table 9 both these hypotheses were rejected; H_1 being rejected at the 0.01 level of confidence and H_2 being rejected at the 0.05 level of confidence.

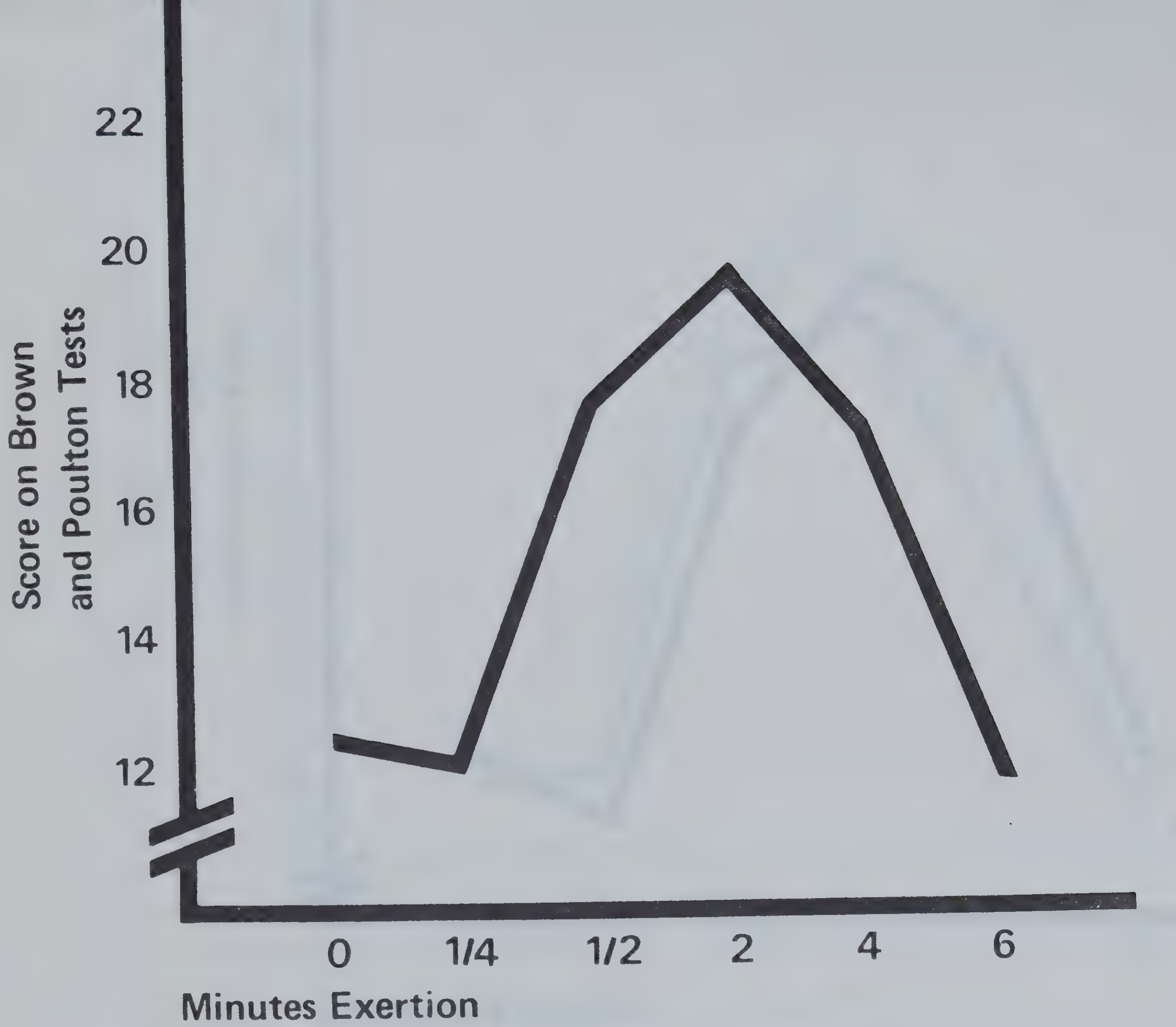
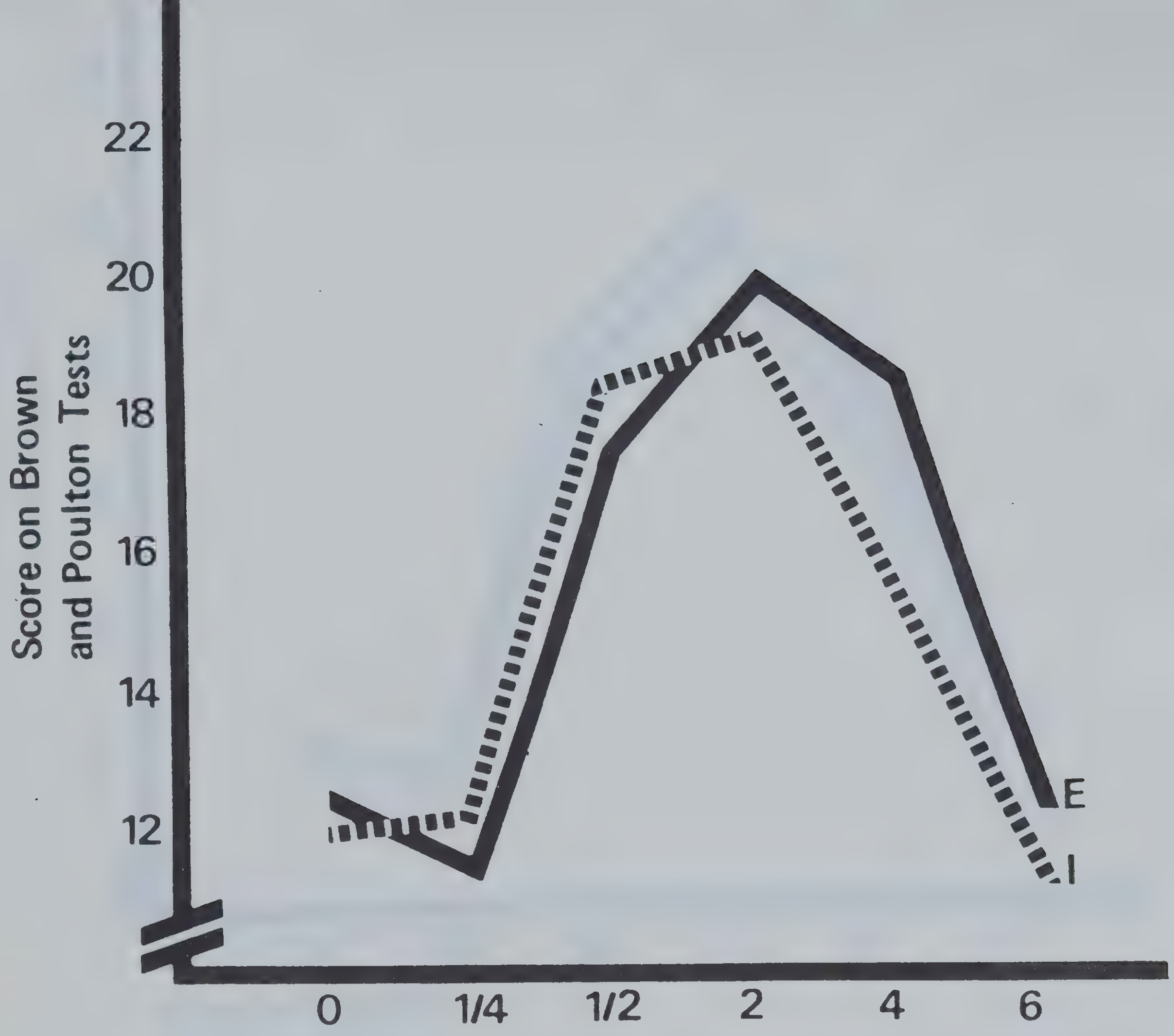


Figure 8 Score on Brown and Poulton Tests after Exertion (N=80)



Minutes Exertion

Figure 9 : Score on Brown and Poulton Test after Exertion, by Personality (E. and I)

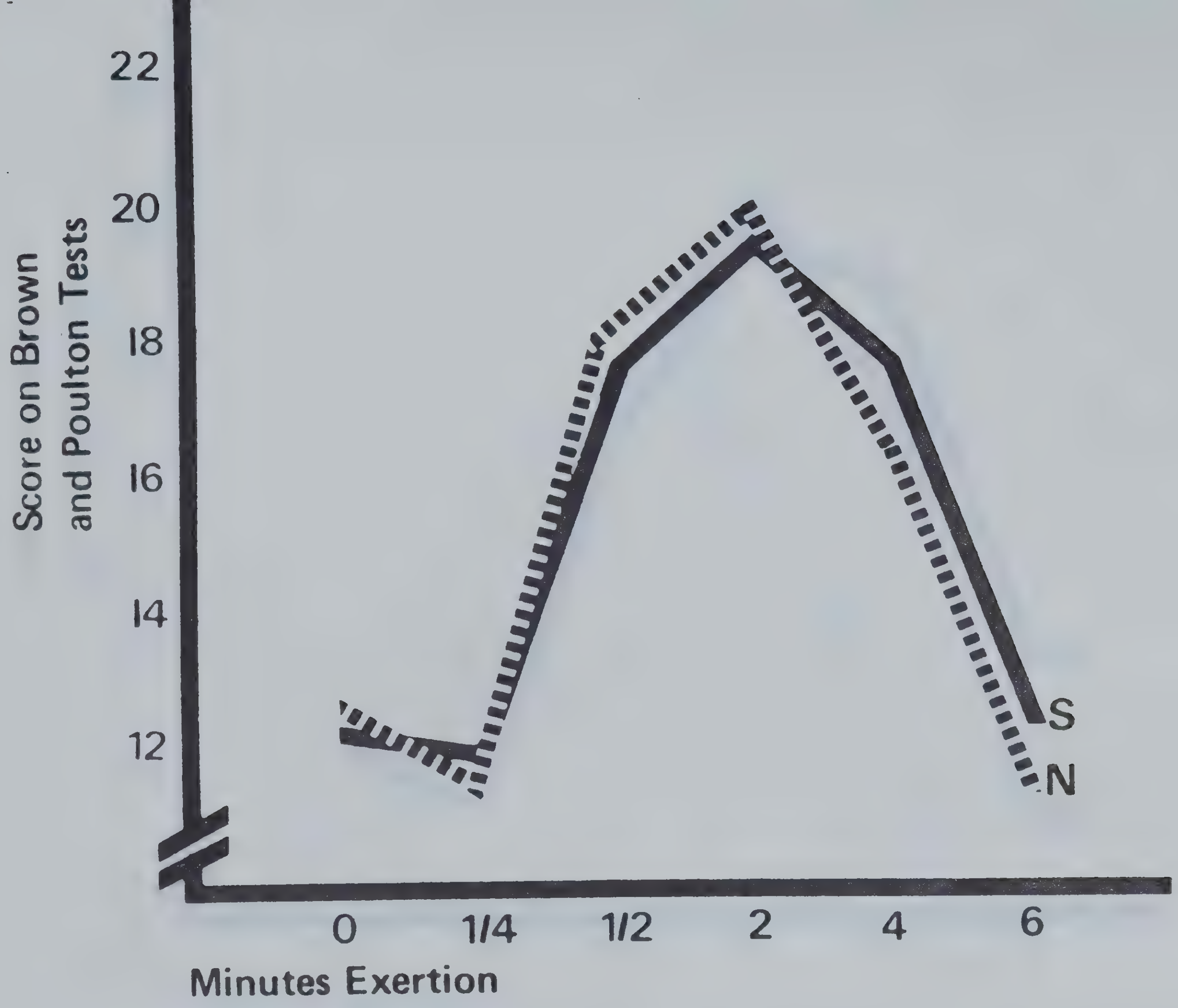


Figure 10 : Score on Brown and Poulton Test after Exertion,
by Personality (S andN)

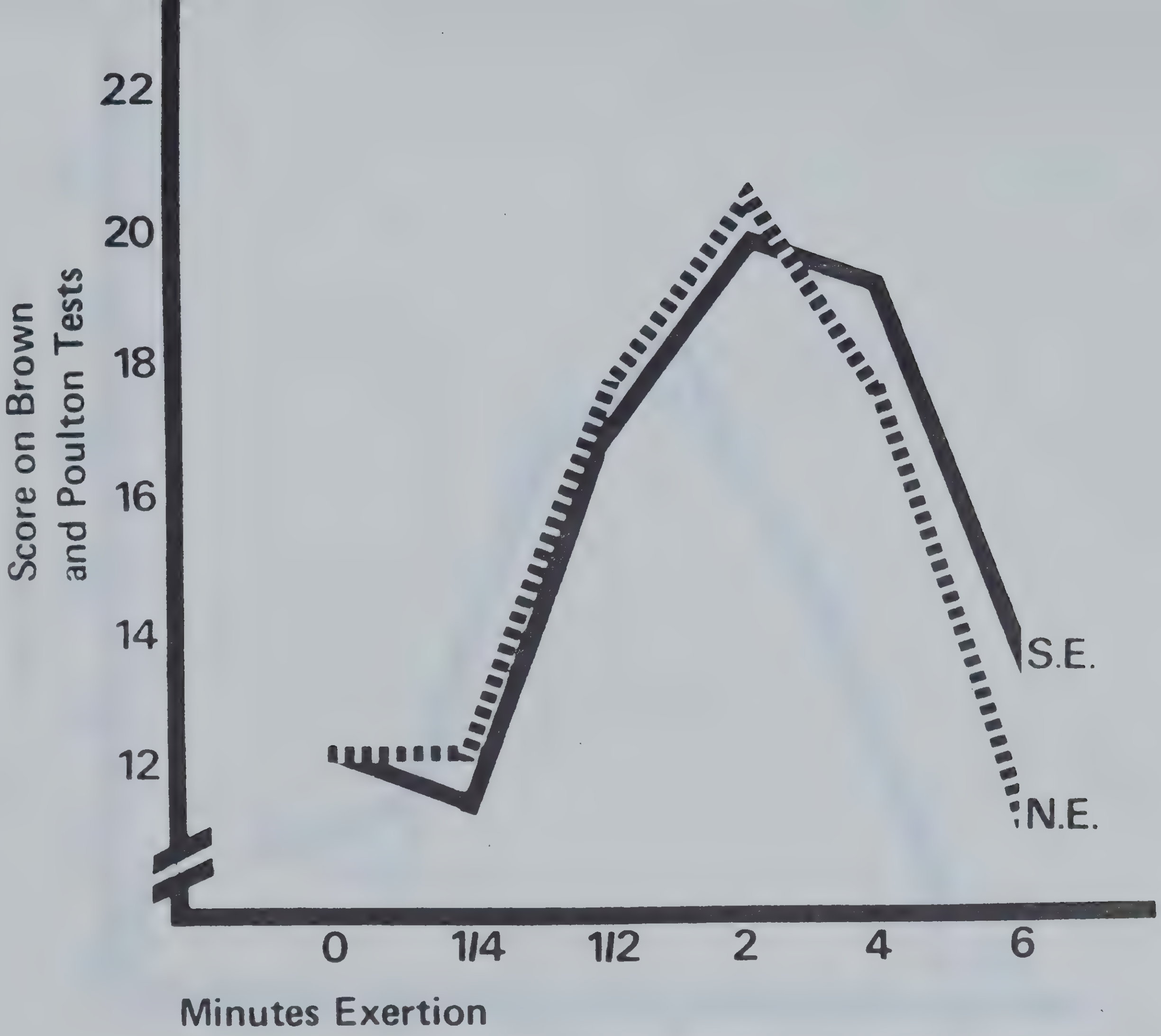


Figure 11 : Score on Brown and Poulton Test after Exertion, by Personality (S.E and NE)

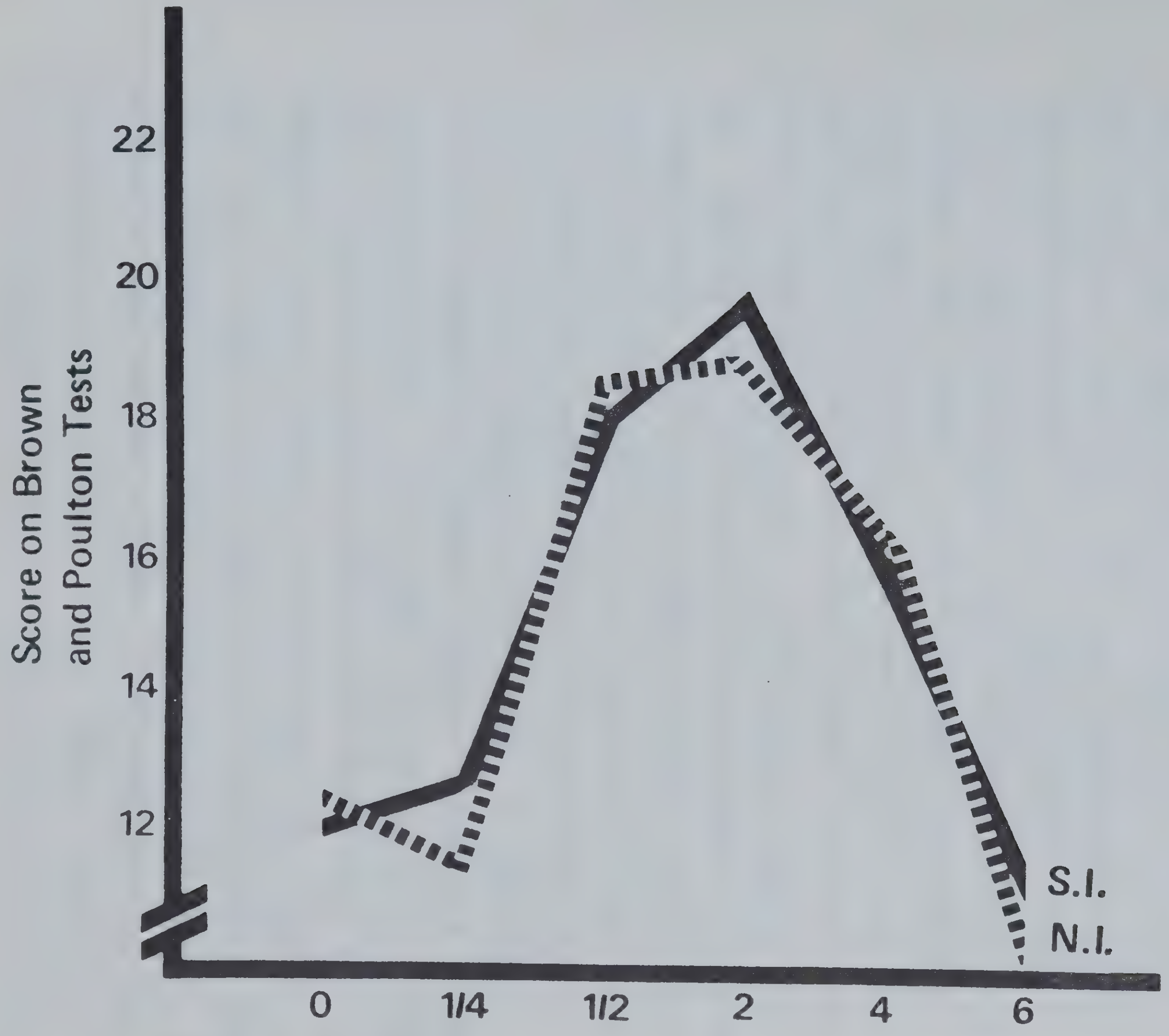


Figure 12 : Score on Brown and Poulton Test after Exertion, by Personality (S.I and N.I)

CHAPTER V

DISCUSSION

Almost no change in mental performance (as measured by the Brown and Poulton test) occurred following the periods of zero and 1/4 minutes of exertion. However after 1/2, 2 and 4 minutes exertion there were significant increases ($p < .01$) in mental performance with the optimal performance being obtained after the 2 minutes exercise period. Furthermore, after 6 minutes of exertion performance deteriorated to slightly below the earlier scores after zero and 1/4 minutes exertion. When Figures 8 to 12 are examined, there is obvious evidence of an inverted U function when performance is plotted against increasing exertion. Each graph shows that as physical exertion increased, it produced an effect upon the subject such that mental performance was facilitated. However, once past the optimal level, performance was inhibited. This is an indication that physical exertion may have altered the level of arousal in the manner hypothesized by Duffy (1962). In these graphs, if the axis representing the duration of physical exertion were replaced by the arousal continuum, it can be clearly seen that as arousal increases from a minimum level, performance improves to an optimal level, and thereafter as arousal increases, performance deteriorates. Hence it appears that the results of this study are consistent with arousal theory. Thus it now remains to find support for the hypothesis that physical exertion can affect the level of arousal. Such an hypothesis has been alluded to by Duffy (1962), Stockfelt (1968), and Gutin (1970), but as yet a satisfactory explanation has not been forthcoming. The following

is offered as an attempted explanation.

It was pointed out in the review of the literature that most recent writers on the topic of behavioral arousal acknowledge its connection with the brain stem reticular formation. Also French (1957) pointed out that the ability to perceive and to think lies in the cortex of the brain, but the brain cannot respond to any stimulus (apart from a reflex action) without being stimulated first by the reticular formation. Therefore, in order for a theory that physical exertion produces arousal to be plausible, it has to be shown that physical exertion stimulates the reticular formation of the brain stem which in turn excites the cortex.

It has been well documented in the physiological literature (von Euler 1969) that the hormone epinephrine is secreted during physical exertion on a bicycle ergometer. Also, as was pointed out in the literature, many writers have shown that the reticular formation is epinephrine - sensitive and that this hormone may, in fact, account for an arousing influence on the cortex. Although perhaps the mechanism is far more complex than this simple explanation, it appears feasible that physical exertion may be one of a number of factors capable of influencing the level of arousal.

One other possible explanation should at least be mentioned. A number of writers (Stauffacher 1937, Pinneo 1961, Andreassi 1965) have suggested that proprioceptive impulses from the musculature also have the ability to arouse the cortex. Since both French (1957) and Hokanson (1969) have shown that sensory signals from all parts of the body (including proprioceptive) feed into the reticular formation on the way to

the cortex, it is possible that such stimulation from exertion may be responsible for the altered state of arousal. It has been shown (Bernhaut et. al. 1953) that apart from pain, proprioceptive stimulation is more likely to produce an arousal reaction than the other senses.

However whether the degree of stimulation from the musculature involved in pedalling the bicycle ergometer is greater or lesser than that produced by induced muscular tension (mentioned in the literature survey as a means of producing arousal) is unknown. It may even be possible that proprioceptive stimulation may occur simultaneously with the suggested stimulation of the reticular formation by epinephrine with a summation effect. At our present state of knowledge this must remain pure speculation.

Further evidence of support for the theory that physical exertion influences the level of arousal may also be seen in the interaction effects of personality and performance as shown in Figures 9 to 12.

As mentioned in the literature, Eysenck stated that extraverts are not as highly aroused as introverts. Therefore, with increasing arousal, it could be predicted from this theory, that introverts would deteriorate in performance before extraverts, and that extraverts could take more stimulation before deteriorating in performance. Figure 9 appears to confirm this prediction. Also the slope of the gradient between 1/2 and 2 minutes exertion for extraversion tends to suggest that extraverts could take more exertion than 2 minutes of stimulation in order to reach their optimal performance level.

However, Eysenck's theory would also predict that neurotic subjects

would reach their optimal level of stimulation earlier with extraversion and introversion held constant. Figures 10 and 12 do not appear to support this prediction but Figure 11 partially supports the prediction in that stable extraversion tends to fall off in performance rather later than neurotic extraversion.

Also of interest is that performance on the short term memory test only began to deteriorate significantly ($p < .01$) after 4 and 6 minutes exertion (Figures 5, 6 and 7). Although there were no significant differences between the interaction of personality and short term memory scores, Figures 6 and 7 show that extraverts perform better on short term memory before and after exertion. Hence these results are consistent with those of Howarth and Eysenck (1968) and with Eysenck's theory that introverts would have poorer immediate recall than extraverts. Though this theory does not make any predictions about performance on short term memory between neurotic and stable subjects, it is of interest to note that after severe exertion both neurotic extraversion and neurotic introversion performed better than stable extraversion and stable introversion respectively, although not significantly. With minor differences these results are similar to those found by McLaughlin and Eysenck (1967).

The inverted U functions between performance and physical exertion shown in Figures 8 to 11 are consistent with the results obtained by Wood and Hokanson (1965) and Stockfelt (1968), both of whom extended the physical exertion over a wide range. The results also concur with the findings of McAdam and Wang (1967), Gutin and Di Gennaro (1968a), Butler (1968) and Zuercher (1965) who found that performance improved

with a sub-maximal amount of physical exertion. Hence it appears that a sub-maximal amount of physical exertion (defined as 1/2 to 2 minutes exertion as used in this study) has a positive effect on performance whereas almost maximal exertion (4 to 6 minutes exertion) has a negative effect on performance. This result is consistent with both Hebb's (1955) and Easterbrook's (1959) theories concerning the energizing (positive) effects of arousal and the interference (negative) effects of arousal.

When Figure 5 is examined it can be seen that there is no increase in capacity of the short term memory but there is a significant ($p < .01$) decrease in capacity after 4 minutes exertion. However Figure 8 shows that with the capacity of the short term memory held constant, processing of information has been improved significantly ($p < .01$) showing the energizing function of sub-maximal exertion. Again when the capacity of the short term memory falls after 6 minutes exertion there is a significant ($p < .01$) deterioration in the processing capacity, showing the interference function after almost maximal exertion.

Biggs (1972) explains the relationship between the energizing and interfering functions of arousal and suggests that at low levels of arousal, energizing is stronger than interference, but at higher levels the interfering function overcomes the energizing one. He suggests that the effect of over-arousal is to take up potentially valuable cognitive space in the short term memory system which reduces the capacity available to process relevant information. This appears to explain why the deterioration of the processing of information in the Brown and Poulton test coincided with the deterioration of performance in the

short term memory test (i.e. 4 minutes exertion).

According to Eysenck (1967) it could be predicted that the point at which arousal changes from an energizing to an interfering function varies for different personality types. This theory was confirmed by the results of this study (Figures 11 and 12) when significant interaction ($p < .05$) effects were obtained for extraversion x neuroticism x exertion.

In Moray's (1970) terms, mental concentration, an important subdivision of attention, has been shown to be facilitated by a sub-maximal amount of physical exertion and inhibited by almost maximal physical exertion. This is in agreement with Butler (1970) who stated that stimulation of the reticular formation not only produces arousal but also affects the transmission and processing of information at the cortex.

Finally this study has shown how physical exertion may influence the level of arousal as defined earlier by Fiske and Maddi (1960) as a neuropsychological concept referring on the neural side to the state of excitation of the reticular formation of the brain stem, and on the psychological side to the common core of such terms as awakeness, alertness, attention and subjective excitement.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to examine the effect of physical exertion on mental performance. It was hypothesized that physical exertion may be one of many factors that influence the level of arousal and hence affect mental performance.

Specifically 80 physical education students were divided into four groups on the basis of their extreme scores on the Eysenck Personality Inventory which measures personality in terms of extraversion-introversion, and neuroticism-stability. Each student was then subjected to varying amounts of physical exertion, after which their mental performance was measured on the Wechsler digit recall short term memory test, and the Brown and Poulton test.

The two null hypotheses, namely:

H_1: there would be no effect in mental performance after various amounts of physical exertion, and

H_2: there would be no difference between the personality divisions in mental performance after various amounts of physical exertion,

were both rejected, H_1 at the 0.01 level of confidence, and H_2 at the 0.05 level of confidence.

A 2 x 2 x 6 (extraversion x neuroticism x exertion) analysis of variance with repeated measures on the last factor was calculated on both tests of mental performance with some significant results. Short term memory scores were found to deteriorate significantly ($p < .01$)

with 4 and 6 minutes exertion but remained almost constant with exertion less than 4 minutes. However, performance on the Brown and Poulton test improved significantly ($p < .01$) after periods of 1/2, 2 and 4 minutes exertion and thereafter performance began to deteriorate with increasing amounts of exertion. These results were consistent with Duffy's view that as arousal increases, performance improves to an optimal level, and thereafter, as arousal increases, performance begins to deteriorate. In support of the concept that physical exertion may produce arousal, some interaction effects between the personality variables of extraversion and neuroticism with exertion were found to be significant ($p < .05$). With the same amount of exertion introverts were found to deteriorate in performance before extraverts, thus lending support to Eysenck's theory that introverts are more highly aroused than extraverts in a resting state, and reach their optimal level earlier with increasing arousal.

A possible explanation of the mechanism by which physical exertion may influence the level of arousal was attempted.

Conclusions

On the basis of the results of this study the following conclusions appear to be justified.

1. There was evidence to suggest that short term memory remains relatively constant with sub-maximal physical exertion but begins to deteriorate significantly as exertion increases towards maximum.
2. In performance on the short term memory test there were no differ-

ences in ability as a function of the four personality categories, stable extraversion, neurotic extraversion, stable introversion and neurotic introversion.

3. There was evidence to suggest that 1/4 minute exertion was not sufficient to improve performance on the Brown and Poulton test but that performance was significantly improved after 1/2 and 2 and 4 minutes exertion.
4. Further increases in physical exertion past the optimal level have an inhibiting effect on performance on the Brown and Poulton test.
5. The personality characteristics of extraversion-introversion appear to have an effect upon the amount of physical exertion to which a person can be subjected before mental performance begins to deteriorate. The evidence suggests that extraverts can take more physical exertion before mental performance is inhibited.

Implications

If the results of the present experiment can be substantiated, one can speculate on certain practical implications. For example, in any learning situation it appears likely that a sub-maximal amount of physical exertion will increase the level of arousal towards the optimal level and hence mental performance will be facilitated. More specifically, in the teaching of physical education, especially in the learning of new skills, the level of arousal may be increased to the optimal level so that the cognitive and perceptual aspects of skill learning are facilitated. Conversely, the physical education teacher should be cognizant

of the reverse situation which may occur if the performer passes the optimal level of arousal through too much exertion.

It also appears likely that a knowledge of the personality characteristics of the performer would assist the physical education teacher in finding the optimal level of arousal for each individual.

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APPENDIX A

EYSENCK PERSONAL INVENTORY

INSTRUCTIONS

Here are some questions regarding the way you behave, feel and act. After each question is a space for answering "Yes", or "No."

Try and decide whether "Yes," or "No" represents your usual way of acting or feeling. Then blacken in the space under the column headed "Yes" or "No."

Work quickly, and don't spend too much time over any question; we want your first reaction, not a long drawn-out thought process. The whole questionnaire shouldn't take more than a few minutes. Be sure not to omit any questions. Now turn the page over and go ahead. Work quickly, and remember to answer every question. There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave.

1. Do you often long for excitement?
2. Do you often need understanding friends to cheer you up?
3. Are you usually carefree?
4. Do you find it very hard to take no for an answer?
5. Do you stop and think things over before doing anything?
6. If you say you will do something do you always keep your promise, no matter how inconvenient it might be to do so?
7. Does your mood often go up and down?
8. Do you generally do and say things quickly without stopping to think?
9. Do you ever feel "just miserable" for no good reason?
10. Would you do almost anything for a dare?
11. Do you suddenly feel shy when you want to talk to an attractive stranger?
12. Once in a while do you lose your temper and get angry?
13. Do you often do things on the spur of the moment?
14. Do you often worry about things you should not have done or said?
15. Generally do you prefer reading to meeting people?
16. Are your feelings rather easily hurt?
17. Do you like going out a lot?
18. Do you occasionally have thoughts and ideas that you would not like other people to know about?
19. Are you sometimes bubbling over with energy and sometimes very sluggish?
20. Do you prefer to have few but special friends?
21. Do you daydream a lot?
22. When people shout at you, do you shout back?
23. Are you often troubled about feelings of guilt?

24. Are all your habits good and desirable ones?

25. Can you usually let yourself go and enjoy yourself a lot at a gay party?

26. Would you call yourself tense or "highly-strung"?

27. Do other people think of you as being very lively?

28. After you have done something important, do you often come away feeling you could have done better?

29. Are you mostly quiet when you are with other people?

30. Do you sometimes gossip?

31. Do ideas run through your head so that you cannot sleep?

32. If there is something you want to know about, would you rather look it up in a book than talk to someone about it?

33. Do you get palpitations or thumping in your heart?

34. Do you like the kind of work that you need to pay close attention to?

35. Do you get attacks of shaking or trembling?

36. Would you always declare everything at the customs, even if you knew that you could never be found out?

37. Do you hate being with a crowd who play jokes on one another?

38. Are you an irritable person?

39. Do you like doing things in which you have to act quickly?

40. Do you worry about awful things that might happen?

41. Are you slow and unhurried in the way you move?

42. Have you ever been late for an appointment or work?

43. Do you have many nightmares?

44. Do you like talking to people so much that you would never miss a chance of talking to a stranger?

45. Are you troubled by aches and pains?

46. Would you be very unhappy if you could not see lots of people most of the time?

47. Would you call yourself a nervous person?

48. Of all the people you know are there some whom you definitely do not like?

49. Would you say you were fairly self-confident?

50. Are you easily hurt when people find fault with you or your work?

51. Do you find it hard to really enjoy yourself at a lively party?

52. Are you troubled with feelings of inferiority?

53. Can you easily get some life into a rather dull party?

54. Do you sometimes talk about things you know nothing about?

55. Do you worry about your health?

56. Do you like playing pranks on others?

57. Do you suffer from sleeplessness?

APPENDIX B

EXTRAVERSION-NEUROTICISM SCORES

	S.E.		N.E.		S.I.		N.I.	
	E	N	E	N	E	N	E	N
	21	7	21	14	11	9	11	20
	19	9	21	11	11	9	11	19
	19	8	20	14	11	8	11	18
	19	7	20	12	11	7	11	17
	19	6	19	21	11	5	11	16
	19	4	19	15	11	4	11	15
	19	2	18	15	10	8	9	19
	18	8	17	17	10	8	9	17
	17	8	17	16	10	7	9	14
	17	6	17	13	10	2	9	13
	17	4	16	19	9	9	9	12
	16	6	16	17	9	9	8	19
	16	2	16	15	9	6	8	13
	15	4	16	14	9	2	8	17
	15	3	15	19	9	1	8	15
	15	2	15	17	8	8	8	12
	14	6	15	15	8	8	8	11
	14	5	14	16	8	5	6	15
	14	4	13	18	8	2	6	13
	13	2	12	19	5	8	6	10
Mean	16.8	5.1	16.8	15.8	9.4	6.2	8.8	15.2
Standard Deviation	2.2	2.2	2.4	2.4	1.4	2.6	1.6	2.8
Percentile	90	21	90	90	30	28	25	88

APPENDIX C

ANALYSIS OF VARIANCE

S.T.M. TEST

	S.S.	d.f.	M.S.	F	p
Between Subjects	244.03	79			
A	4.80	1	4.80	1.54	N.S.
B	2.13	1	2.13	0.68	N.S.
AB	0.30	1	0.30	0.09	N.S.
Subjects Within Groups	236.8	76	3.11		
Within Subjects	160.34	400			
C	24.97	5	4.99	14.67	< .01
AC	2.80	5	0.56	1.64	N.S.
BC	1.87	5	0.37	1.08	N.S.
ABC	0.30	5	0.06	0.17	
CX Subjects Within Groups	130.4	380	0.34		

ANALYSIS OF VARIANCE

S.T.M. TEST

ABC Summary Table

		C_1	C_2	C_3	C_4	C_5	C_6	Total
a_1	b_1	142	140	144	140	136	132	834
	b_2	148	144	142	144	140	138	856
a_2	b_1	140	138	142	142	132	122	816
	b_2	142	138	140	142	122	128	826
		572	560	568	568	128	520	3332

AB Summary Table

	b_1	b_2	Total
a_1	834	856	1690
a_2	816	826	1642
	1650	1682	3332

AC Summary Table

	C_1	C_2	C_3	C_4	C_5	C_6	Total
a_1	290	284	286	284	276	270	1690
a_2	282	276	282	284	268	250	1642
	572	560	568	568	544	520	3332

BC Summary Table

	C_1	C_2	C_3	C_4	C_5	C_6	Total
b_1	282	278	286	282	268	254	1650
b_2	290	282	282	282	276	266	1682
	572	560	568	568	544	520	3332

ANALYSIS OF VARIANCE

S.T.M. TEST

$n = 20 \qquad p = 2 \qquad q = 2 \qquad r = 6$

(I) $G^2/npqr = \dfrac{3332^2}{(2)(2)(6)(20)} = \dfrac{11,102,224}{480} = 23,129.63$

(II) $\Sigma X^2 = 23,534.00$

(III) $\Sigma A^2/nqr = \dfrac{1690^2 + 1642^2}{(20)(2)(6)} = \dfrac{5,552,264}{240} = 23,134.43$

(IV) $\Sigma B^2/npr = \dfrac{1650^2 + 1682^2}{(20)(2)(6)} = \dfrac{5,551,624}{240} = 23,131.76$

(V) $\Sigma C^2/npq = \dfrac{572^2 + 560^2 + 568^2 + 544^2 + 520^2}{(20)(2)(2)} = \dfrac{1,852,368}{80} = 23,154.60$

(VI) $\Sigma AB^2/np = \dfrac{834^2 + 856^2 + 816^2 + 826^2}{(20)(6)} = \dfrac{2,776,424}{120} = 23,136.86$

(VII) $\Sigma AC^2/nq = \dfrac{290^2 + \ldots + 250^2}{(20)(2)} = \dfrac{926,488}{40} = 23,162.20$

(VIII) $\Sigma BC/np = \dfrac{282^2 + \ldots + 266^2}{(20)(2)} = \dfrac{926,344}{40} = 23,158.60$

(IX) $\Sigma ABC/n = \dfrac{142^2 + \ldots + 128^2}{(20)} = \dfrac{463,336.0}{20} = 23,166.80$

(X) $\Sigma P^2/r = \dfrac{48^2 + \ldots + 35^2}{(6)} = \dfrac{140,242}{6} = 23,373.66$

NEWMAN KEULS

S.T.M. TEST

Exertion		C_6	C_5	C_2	C_3	C_4	C_1
Ordered Means		6.5	6.8	7.0	7.1	7.1	7.2
	C_6	-	0.3	0.5	0.6	0.6	0.7
	C_5		-	0.2	0.3	0.3	0.4
Differences	C_2			-	0.1	0.1	0.2
Between Pairs	C_3				-	0.0	0.1
	C_4					-	0.1
	C_1						-
	$S_{\overline{C}} = .09$		2	3	4	5	6
	.95(r,380)		2.77	3.31	3.63	3.86	4.03
	$S_{\overline{C}}$ .95(r,380)		0.25	0.29	0.32	0.34	0.36

	C_6	C_5	C_2	C_3	C_4	C_1
C_6	-	*	*	*	*	*
C_5		-	-	*	*	*
C_2			-	-	-	-
C_3				-	-	-
C_4					-	-
C_1						-

$$S_{\overline{C}} = \sqrt{\frac{\text{MSc x subjects within group}}{\text{np}}} = \sqrt{\frac{0.34}{(20)(2)}}$$

$$= \sqrt{.0085} = .09$$

S.E. (S.T.M. SCORES)

Subject	0	1/4	1/2	2	4	6	Total
1	9	8	9	8	7	7	48
2	8	8	8	9	8	8	49
3	8	8	9	8	7	7	47
4	8	7	8	7	7	7	44
5	8	7	7	7	7	7	43
6	8	7	8	8	8	8	47
7	7	8	8	8	7	7	45
8	7	7	8	7	7	7	43
9	7	7	7	7	7	7	42
10	7	7	7	6	6	6	39
11	7	7	6	7	7	7	41
12	7	6	7	7	7	6	40
13	7	7	6	6	6	6	38
14	7	7	7	7	7	7	42
15	7	6	6	7	6	6	38
16	6	7	7	7	7	7	41
17	6	7	7	6	6	6	38
18	6	6	6	6	6	5	35
19	6	7	7	6	7	6	39
20	6	6	6	6	6	5	35
ΣX	142	140	144	140	136	132	834
ΣX^2	1058	988	1054	994	932	884	5910

N.E. (S.T.M. SCORES)

Subject	0	1/4	1/2	2	4	6	Total
1	9	9	9	9	8	9	53
2	9	8	8	8	7	7	47
3	8	9	8	9	8	8	50
4	8	8	7	8	8	7	46
5	8	7	7	7	7	7	43
6	8	8	8	8	8	8	48
7	8	7	7	7	7	7	43
8	8	7	7	7	7	7	43
9	8	7	7	7	7	7	43
10	8	8	8	8	7	8	47
11	7	7	7	7	7	6	41
12	7	8	8	8	7	7	45
13	7	7	7	7	7	7	42
14	7	6	6	6	7	6	38
15	7	6	6	6	6	6	37
16	7	7	7	7	7	7	42
17	6	6	6	6	6	6	36
18	6	7	7	7	7	7	41
19	6	6	6	6	6	5	35
20	6	6	6	6	6	6	36
ΣX	148	144	142	144	140	138	856
ΣX^2	1112	1054	1022	1054	988	968	6198

S.I. (S.T.M. SCORES)

Subject	0	1/4	1/2	2	4	6	Total
1	9	8	9	8	8	8	50
2	8	7	8	8	7	7	45
3	8	8	8	8	8	8	48
4	8	7	7	8	7	6	43
5	8	8	8	8	7	6	45
6	7	7	7	7	7	7	42
7	7	7	8	8	7	6	43
8	7	7	7	7	6	6	40
9	7	7	8	8	7	7	44
10	7	7	7	7	6	6	40
11	7	7	7	7	6	6	40
12	7	6	6	6	6	5	36
13	7	7	7	7	6	6	40
14	7	7	7	7	7	6	41
15	6	7	7	7	6	6	39
16	6	6	6	6	6	5	35
17	6	7	7	7	7	6	40
18	6	6	6	6	6	5	35
19	6	6	6	6	6	5	35
20	6	6	6	6	6	5	35
ΣX	140	138	142	142	132	122	816
ΣX^2	994	960	1022	1020	880	760	5636

N.I. (S.T.M. SCORES)

Subject	0	1/4	1/2	2	4	6	Total
1	9	8	8	9	8	8	50
2	8	8	7	8	7	7	45
3	8	7	8	8	7	7	45
4	8	7	7	7	7	7	43
5	8	8	8	8	8	7	47
6	8	7	7	7	7	7	43
7	7	7	8	8	7	7	44
8	7	6	7	7	6	6	39
9	7	7	7	8	7	7	43
10	7	7	7	7	7	6	41
11	7	7	7	7	7	7	42
12	7	7	7	7	7	6	41
13	7	7	7	7	7	6	41
14	7	6	6	6	6	6	37
15	7	7	7	7	7	6	41
16	6	7	6	6	6	6	37
17	6	7	7	7	7	6	40
18	6	6	7	6	6	6	37
19	6	6	6	6	6	5	35
20	6	6	6	6	6	5	35
ΣX	142	138	140	142	136	128	826
ΣX^2	1058	960	988	1022	932	830	5790

APPENDIX D

ANALYSIS OF VARIANCE

BROWN AND POULTON TEST

	S.S.	d.f.	M.S.	F	p
Between Subjects	4205.1	79			
A	53.3	1	53.3	0.97	N.S.
B	7.5	1	7.5	0.13	N.S.
AB	2.7	1	2.7	0.04	N.S.
Subjects Within Groups	4141.6	76	54.4		
Within Subjects	5827.7	400			
C	4964.0	5	992.8	661.86	< .01
AC	176.7	5	35.3	23.53	< .01
BC	36.7	5	7.3	4.86	< .05
ABC	52.7	5	10.5	7.00	< .05
C x Subjects Within Groups	597.6	380	1.5		

ANALYSIS OF VARIANCE

BROWN AND POULTON TEST

AB Summary Table

	b_1	b_2	Total
a_1	1870	1822	3692
a_2	1772	1760	3532
	3642	3582	7224

AC Summary Table

	C_1	C_2	C_3	C_4	C_5	C_6	Total
a_1	492	472	696	804	740	488	3692
a_2	484	488	728	768	624	440	3532
	976	960	1424	1572	1372	1364	7224

BC Summary Table

	C_1	C_2	C_3	C_4	C_5	C_6	Total
b_1	486	482	704	784	700	486	3642
b_2	490	478	720	788	664	442	3582
	976	960	1424	1572	1364	928	7224

ABC Summary Table

		C_1	C_2	C_3	C_4	C_5	C_5	Total
a_1	b_1	246	230	344	396	390	264	1870
	b_2	246	242	352	408	350	224	1822
a_2	b_1	240	252	360	388	310	222	1772
	b_2	244	236	368	380	314	218	1760
		976	960	1424	1572	1364	928	7224

ANALYSIS OF VARIANCE

BROWN AND POULTON TEST

p = 2 q = 2 r = 6 n = 20

$$(1) = G^2/npqr = \frac{7224^2}{(2)(2)(6)(20)} = \frac{52186176}{480} = 108{,}721.2$$

$$(2) = X^2 = 16^2 + \ldots\ 6^2 = 118{,}754$$

$$(3) = A^2/nqr = \frac{3692^2 + 3532^2}{(20)(2)(6)} = \frac{26{,}105{,}888}{240} = 108{,}774.533$$

$$(4) = B^2/npr = \frac{3642^2 + 3582^2}{(20)(2)(6)} = \frac{26{,}094{,}888}{240} = 108{,}728.7$$

$$(5) = C^2/npq = \frac{976^2 + 960^2 + 1424^2 + 1572^2 + 1364^2 + 928^2}{(20)(2)(2)}$$

$$= \frac{9094816}{80} = 113685.2$$

$$(6) = AB^2/nr = \frac{1870^2 + 1822^2 + 1772^2 + 1760^2}{(20)(6)} = \frac{13{,}054{,}168}{120}$$

$$= 108{,}784.7333$$

$$(7) = AC^2/nq = \frac{492^2\ \ldots\ 440^2}{(20)(2)} = \frac{4{,}556{,}608}{40} = 113{,}915.2$$

$$(8) = BC^2/np = \frac{486^2\ \ldots\ 442^2}{(20)(2)} = \frac{4{,}549{,}176}{40} = 113{,}729.4$$

$$(9) = ABC^2/n = \frac{246^2\ \ldots\ 218^2}{(20)} = \frac{2{,}280{,}296}{20} = 114{,}014.8$$

$$(10) = P^2/r = \frac{117^2\ \ldots\ 58^2}{(6)} = \frac{677{,}558}{6} = 112{,}926.3333$$

NEWMAN KEULS

BROWN AND POULTON TEST

Main Effects of Factor C

Ordered Means		11.6	12.0	12.2	17.0	17.8	19.5
Exertion		C_6	C_2	C_1	C_5	C_3	C_4
	C_6		0.4	0.6	5.4	6.2	7.9
	C_2			0.2	5.0	5.8	7.5
Differences	C_1				4.8	5.6	7.3
Between Pairs	C_5					0.8	2.5
	C_3						1.7
	C_4						

$S_{\bar{C}} = .19$	$r =$	2	3	4	5	6
$.95(r,380)$		2.77	3.31	3.63	3.86	4.03
$S_{\bar{C}}\ .95(r,380)$		0.52	0.62	0.68	0.73	0.76

$$S_{\bar{C}} = \sqrt{\frac{MS_{\bar{C}} \text{ x subjects within groups}}{np}}$$

$$= \sqrt{\frac{1.5}{(20)(2)}}$$

$$= \sqrt{\frac{1.5}{40}} = \sqrt{0.0375}$$

$$= .19$$

	C_6	C_2	C_1	C_5	C_3	C_4
C_6	-	-	-	*	*	*
C_2		-	-	*	*	*
C_1			-	*	*	*
C_5				-	*	*
C_3					-	*
C_4						-

NEWMAN KEULS

BROWN AND POULTON TEST

Simple Main Effects of C_5

$$SS_a \text{ at } C_5 = \frac{740^2 + 624^2}{40} - \frac{1364^2}{80} = 168.2$$

$$MS_a \text{ at } C_5 = \frac{168.2}{p-1} = 168.2$$

$$MS_{w.cell} = \frac{SS_{w.cell}}{pr(n-1)} = \frac{4739.2}{228} = 20.7$$

$$F = \frac{MS_a \text{ at } C_5}{MS_{w.cell}} \doteq \frac{168.2}{20.7} = 8.12 \ (p < .01)$$

Newman Keuls (a at C_5)

		S.I.	N.I.	N.E.	S.E.
Ordered Means		15.5	15.7	17.5	19.5
S.I.		-	0.2	2.0	4.0
N.I.			-	1.8	3.8
N.E.				-	2.0
S.E.					-
$S_{\overline{A}} = .67$		r =	2	3	4
q(.95)(r,38)			2.86	3.44	3.79
$S_{\overline{A}}$q(.95)(r,38)			1.92	2.30	2.53

	S.I.	N.I.	N.E.	S.E.
S.I.	-	-	*	*
N.I.		-	-	*
N.E.			-	*
S.E.				-

$$S_{\overline{A}} = \sqrt{\frac{MS \text{ subj. w. groups}}{nr}} = \sqrt{\frac{54}{(20)(6)}} = 0.67$$

BROWN AND POULTON SCORES

S.E.

Subject	0	1/4	1/2	2	4	6	Total
1	16	18	20	23	23	17	117
2	16	15	21	22	20	15	109
3	15	17	22	25	24	21	124
4	15	14	20	22	20	15	106
5	14	13	19	21	21	19	107
6	13	14	20	24	22	13	106
7	13	13	18	20	22	18	104
8	13	12	16	21	21	14	97
9	13	13	18	21	19	14	98
10	12	12	17	20	19	13	93
11	12	12	18	20	21	14	97
12	12	9	17	19	19	11	87
13	12	8	17	18	20	12	87
14	12	10	15	19	18	10	84
15	11	10	17	19	18	12	87
16	11	9	15	17	18	8	78
17	11	7	12	14	15	10	69
18	9	8	15	18	17	10	77
19	8	8	13	17	17	9	72
20	8	8	14	16	16	9	71
Total	246	230	344	396	390	264	1870
Mean	12.3	11.5	17.2	19.8	19.5	13.2	
Standard Deviation	2.2	3.0	2.6	2.6	2.2	3.4	

BROWN AND POULTON SCORES

N.E.

Subject	0	1/4	1/2	2	4	6	Total
1	18	18	22	24	22	14	118
2	16	19	22	23	20	13	113
3	16	15	20	20	21	12	104
4	15	16	24	26	22	15	118
5	15	14	21	24	22	14	110
6	14	13	19	22	18	15	101
7	14	14	21	23	20	13	105
8	13	13	18	22	19	13	98
9	13	12	18	21	18	11	93
10	12	11	17	20	19	12	91
11	12	12	18	21	16	11	90
12	12	11	17	20	17	10	87
13	11	12	17	19	16	9	84
14	11	10	13	17	17	11	79
15	11	11	16	20	17	10	85
16	10	9	14	18	13	11	75
17	10	10	16	19	12	7	74
18	9	8	14	17	13	9	70
19	8	7	12	15	14	6	62
20	6	7	13	17	14	8	65
Total	246	242	352	408	350	224	1822
Mean	12.3	12.1	17.6	20.4	17.5	11.2	
Standard Deviation	2.8	3.2	3.2	2.7	3.0	2.4	

BROWN AND POULTON SCORES

S.I.

Subject	0	1/4	1/2	2	4	6	Total
1	17	17	23	25	21	16	119
2	17	19	22	24	19	13	114
3	15	18	24	23	20	14	114
4	15	16	20	21	17	12	101
5	14	17	21	22	22	17	113
6	14	14	20	19	18	13	98
7	13	15	23	21	19	15	106
8	13	14	18	18	15	14	92
9	12	12	19	20	17	11	91
10	12	12	17	19	14	9	83
11	12	13	18	20	16	12	91
12	12	11	17	18	15	10	83
13	11	12	18	19	16	11	87
14	11	9	15	19	12	8	74
15	10	11	18	18	13	9	79
16	10	8	14	17	12	7	68
17	9	10	16	19	14	9	77
18	8	9	12	15	10	8	62
19	8	8	14	17	11	6	64
20	7	7	11	14	9	8	56
Total	240	252	360	388	310	222	1772
Mean	12.0	12.6	18.0	19.4	15.5	11.1	
Standard Deviation	2.7	3.4	3.5	2.6	3.5	3.0	

BROWN AND POULTON SCORES

N.I.

Subject	0	1/4	1/2	2	4	6	Total
1	20	18	24	24	20	15	121
2	17	19	25	24	21	14	120
3	16	15	22	22	19	15	109
4	16	14	21	23	21	16	111
5	15	15	23	24	17	12	106
6	14	13	24	20	18	13	102
7	13	14	22	22	16	12	99
8	13	12	21	21	17	14	98
9	13	12	18	21	15	12	91
10	12	11	21	19	16	9	88
11	12	12	17	18	16	9	84
12	12	11	18	19	15	10	85
13	11	12	17	21	14	8	83
14	11	10	19	19	15	10	84
15	10	9	12	15	13	8	67
16	9	10	17	17	12	10	75
17	8	10	15	15	13	7	68
18	8	6	11	11	11	7	54
19	8	5	10	11	12	11	57
20	6	8	11	14	13	6	58
Total	244	236	368	380	314	218	1760
Mean	12.2	11.8	18.4	19.0	15.7	10.9	
Standard Deviation	3.4	3.4	4.5	3.9	2.9	2.8	

APPENDIX E

INSTRUCTIONS TO SUBJECTS

In this experiment we are studying the way people perform on two tests of mental performance after varying amounts of physical exertion taken on the bicycle ergometer.

Sit on the bicycle ergometer and I shall adjust the seat and the pedals until you feel quite comfortable. This thumb cuff measures your heart rate at various stages.

In the first test I am going to say some numbers. Listen carefully and when I am finished say them after me in the same order.

In the second test you will hear a continuous series of numbers from the tape recorder. Again listen carefully and every time you detect a sequence in the order, "odd-even-odd", say "Yes". Try and say yes before you hear the next number, eg., if you hear the numbers 1, 6, 5 you say, "yes", or if you hear the numbers 1, 6, 5, 6, 7, you would say "yes" after the 5 and "yes" again after the 7.

After a short period you will be told to rest so would you please remain on the bike and relax.

At various stages I shall ask you to pedal the bicycle ergometer trying to keep this needle of the revolution counter as near as possible to the red marker. When told to stop, be ready to commence the mental tasks again.

You will no doubt be interested in the purpose of the experiment and I will be happy to explain this to you at the end of the experiment.

Are there any questions about what you have to do?

APPENDIX F

S.T.M. SCORE SHEET

I	2 9 1 4 3	4 6 3 5 9
	7 9 8 2 1 5	5 7 2 1 8 4
	3 1 7 4 9 8 5	1 3 2 6 4 7 5
	8 6 1 9 2 7 4 3	7 1 6 5 3 2 4 9
	7 2 6 4 1 9 3 8 5	8 1 7 4 6 5 2 9 3
	9 1 4 7 3 8 6 2 5 4	8 3 6 1 7 9 4 5 2 6
II	9 2 4 1 3	6 5 3 9 4
	9 2 7 1 8 5	7 2 5 8 4 1
	1 7 4 9 3 5 8	2 6 3 1 5 7 4
	6 1 9 2 8 3 7 4	6 1 3 7 2 5 9 4
	2 7 4 1 6 9 8 5 3	7 4 1 8 6 9 3 5 2
	7 9 6 2 4 8 1 5 3 6	1 7 6 4 9 5 3 8 2 6
III	3 4 1 9 2	9 5 3 6 4
	5 1 8 2 9 7	4 8 1 7 2 5
	5 8 9 4 7 1 3	5 7 4 6 2 1 3
	3 7 4 2 9 1 6 8	9 2 5 6 4 3 1 7
	5 8 3 9 1 4 6 2 7	3 9 2 5 6 4 7 1 8
	4 6 2 5 8 3 7 4 1 9	6 2 5 4 9 7 1 6 3 8
IV	3 1 4 2 9	3 6 4 9 5
	7 9 2 5 1 8	5 2 7 4 8 1
	4 7 1 3 5 8 9	6 2 1 3 5 7 4
	1 6 8 3 7 4 2 9	4 3 1 7 9 2 5 6
	1 4 6 2 7 5 8 3 9	6 4 7 1 8 3 9 2 5
	9 1 4 8 3 7 4 6 2 5	6 3 8 2 5 4 6 9 7 1

V	1 4 3 2 9	3 4 6 5 9
	8 2 1 5 7 9	7 2 4 8 1 5
	4 9 8 5 3 1 7	6 4 7 5 1 3 2
	9 2 7 4 8 3 6 1	5 3 4 2 9 7 1 6
	4 1 9 3 8 5 7 2 6	4 6 5 2 9 3 8 1 7
	4 7 3 8 6 2 5 4 9 1	6 1 7 9 4 5 2 6 8 3
VI	9 2 4 1 3	4 9 3 6 5
	2 7 1 9 5 8	2 7 8 4 5 1
	3 5 8 9 4 7 1	1 5 7 2 6 4 3
	8 4 7 3 6 1 9 2	4 6 7 9 2 5 3 1
	7 4 1 6 9 2 8 3 5	8 6 9 3 5 2 7 1 4
	9 6 4 2 8 1 5 9 3 7	6 4 9 7 1 5 3 6 8 2
VII	4 3 1 9 2	6 5 9 4 3
	1 5 8 2 7 9	1 4 8 5 7 2
	9 8 5 3 4 7 1	5 2 7 6 3 1 4
	2 8 7 4 6 3 1 9	2 5 9 4 6 3 1 7
	6 9 5 8 3 2 7 4 1	1 8 6 9 3 5 2 7 4
	5 3 6 8 7 9 4 2 1 3	4 9 5 3 8 2 6 1 7 5
VIII	2 9 1 4 3	4 9 3 6 5
	7 9 1 5 2 8	8 5 7 2 1 4
	8 3 7 5 4 1 9	7 6 3 4 1 5 2
	7 3 6 1 9 2 8 4	5 2 9 6 4 1 3 7
	5 8 3 7 2 4 1 6 9	6 3 5 9 2 7 4 1 8
	6 9 8 7 4 2 1 3 5 8	5 8 3 2 6 7 5 1 4 9

APPENDIX G

BROWN AND POULTON TEST

SCORE SHEET

4	7	8	1*	8	3*	2	3*	5	3	4	2	3	9	5	9	5	4	3*	8
4	6	1	7	6	8	7	2	8	3	9	8	7*	1	6	1*	9	4	1*	6
8	2	5	4	3*	4	9*	4	9*	8	4	2	7	8	5*	2	1*	3	2	9*
7	3	4	9*	2	7*	9	3	5	1	4	9*	2	8	7	8	5*	7	3	7
4	2	1	2	5*	4	3*	9	1	8	1*	2	9*	1	9	8	2	7	2	8
5	9	2	7*	8	2	1	4	3*	5	3	5	4	9*	1	3	7	1	8	3*
8	9*	7	1	9	3														

3	9	1	7	9	8	3*	8	1*	7	3	1	9	4	5*	3	5	3	4	1*
2	8	7	2	9*	5	8	2	7	2	8	9	1	9	2	1*	8	1*	9	3
4	5*	2	1*	2	4	7	3	7	5	8	7*	8	2	9	4	1*	5	3	9
7	2	9*	4	3*	7	9	2	3*	1	2	5*	8	7*	2	4	8	9	4	9*
4	3*	4	5*	2	8	6	1	4	9*	1	6	1*	7	8	9*	3	8	2	7
8	6	7	1	6	4	8	3	4	5*	9	5	9	3	2	4	3	5	3	2
3*	8	1*	8	7*	4														

4	7	8	1*	8	3*	2	3*	5	3	4	2	3	9	5	9	5	4	3*	8
4	6	1	7	6	8	7	2	8	3	9	8	7*	1	6	1*	9	4	1*	6
8	2	5	4	3*	4	9*	4	9*	8	4	2	7	8	5*	2	1*	3	2	9*
7	3	4	9*	2	7*	9	3	5	1	4	9*	2	8	7	8	5*	7	3	7
4	2	1	2	5*	4	3*	9	1	8	1*	2	9*	1	9	8	2	7	2	8
5	9	2	7*	8	2	1	4	3*	5	3	5	4	9*	1	3	7	1	8	3*
8	9*	7	1	9	3														

3	9	1	7	9	8	3*	8	1*	7	3	1	9	4	5*	3	5	3	4	1*
2	8	7	2	9*	5	8	2	7	2	8	9	1	9	2	1*	8	1*	9	3
4	5*	2	1*	2	4	7	3	7	5	8	7*	8	2	9	4	1*	5	3	9
7	2	9*	4	3*	7	9	2	3*	1	2	5*	8	7*	2	4	8	9	4	9*
4	3*	4	5*	2	8	6	1	4	9*	1	6	1*	7	8	9*	3	8	2	7
8	6	7	1	6	4	8	3	4	5*	9	5	9	3	2	4	3	5	3	2
3*	8	1*	8	7*	4														

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4 7 8 3* 8 5* 2 5* 3 5 4 2 3 9 5 9 5 4 5* 8
4 6 1 7 6 8 7 2 8 3 9 8 9* 1 6 3* 9 4 3* 6
8 2 5 4 5* 4 1* 4 1* 8 4 2 7 8 7* 2 3* 5 2 1*
7 3 4 1* 2 9* 3 5 1 4 1* 2 8 7 8 7* 3 7 3 4
2 1 2 7* 4 5* 9 1 8 3* 2 9* 1 9 8 2 7 2 8 5
9 2 9* 8 2 1 4 5* 3 5 3 5 4 9* 1 3 7 1 8 3*
8 1* 9 7 1 9

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3 9 1 7 9 8 5* 8 3* 7 3 1 9 4 7* 3 5 3 4 3*
2 8 7 2 1* 5 8 2 7 2 8 9 1 9 2 3* 8 3* 9 3
4 7* 2 3* 2 4 7 3 7 5 8 9* 8 2 9 4 3* 5 3 9
7 2 1* 4 5* 7 9 2 3* 1 2 5* 8 9* 2 4 8 9 4 1*
4 5* 4 7* 2 8 6 1 4 1* 3 6 3* 7 8 7* 3 8 2 7
8 6 7 1 6 4 8 3 4 7* 9 5 9 3 2 4 3 5 3 2
5* 8 3* 8 9* 4

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4 7 8 3* 8 5* 2 5* 3 5 4 2 3 9 5 9 5 4 5* 8
4 6 1 7 6 8 7 2 8 3 9 8 9* 1 6 3* 9 4 3* 6
8 2 5 4 5* 4 1* 4 1* 8 4 2 7 8 7* 2 3* 5 2 1*
7 3 4 1* 2 9* 3 5 1 4 1* 2 8 7 8 7* 3 7 3 4
2 1 2 7* 4 5* 9 1 8 3* 2 9* 1 9 8 2 7 2 8 5
9 2 9* 8 2 1 4 5* 3 5 3 5 4 9* 1 3 7 1 8 3*
8 1* 9 7 1 9

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3 9 1 7 9 8 5* 8 3* 7 3 1 9 4 7* 3 5 3 4 3*
2 8 7 2 1* 5 8 2 7 2 8 9 1 9 2 3* 8 3* 9 3
4 7* 2 3* 2 4 7 3 7 5 8 9* 8 2 9 4 3* 5 3 9
7 2 1* 4 5* 7 9 2 3* 1 2 5* 8 9* 2 4 8 9 4 1*
4 5* 4 7* 2 8 6 1 4 1* 3 6 3* 7 8 7* 3 8 2 7
8 6 7 1 6 4 8 3 4 7* 9 5 9 3 2 4 3 5 3 2
5* 8 3* 8 9* 4

APPENDIX H

MEAN HEART RATES AFTER EXERTION

Minutes Exertion	0	1/4	1/2	2	4	6
Mean Heart Rate (B.P.M.)	75	92	104	121	138	154
Range	56-81	70-105	82-119	95-134	121-152	138-168